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Metal Progress

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Ernest E. Thum, Editor

Metal Progress

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Great plans are in the making for the October issue, to be in the mails ten days prior to the opening of the National Metal Congress and the Annual Convention. It will be ten magazines in one, each in its own cover, each reviewing recent progress in one branch of the metal industry. Is your Company to be adequately represented in its pages?

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AMERICAN SOCIETY for METALS

by R. L. Wilson
Metallurgical Engineer
Timken Steel & Tube Co.
Canton, Ohio

Low alloy steels for oil refinery service

NEW DEVELOPMENTS in the refining of corrosive crude oils and the cracking processes operating at higher pressures and transfer temperatures have been largely responsible for the application of alloy steels in the construction of oil refinery equipment. As the use of the so-called stainless steels (containing 18% chromium, more or less) cannot be justified in many instances, the less expensive 4 to 6% chromium steel and the modified analyses containing tungsten or molybdenum have become popular for certain purposes — especially when the initial cost of equipment must be depreciated at a rapid rate to keep pace with technical developments in the industry. All the 4 to 6% chromium steels have been used in substantial tonnage, although the present tendency is toward the composition containing 0.50% molybdenum.

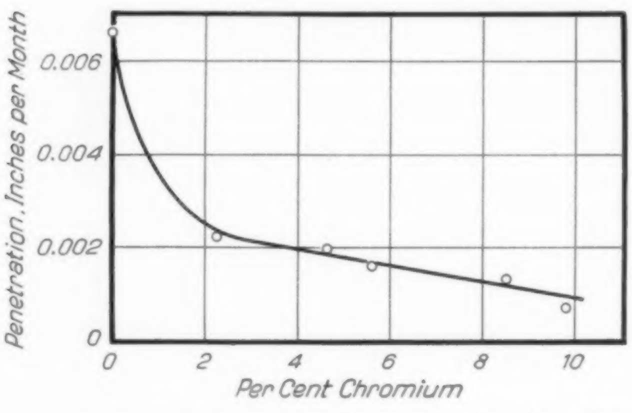
The principal applications have been in cracking furnace tubes, heat exchanger tubes, transfer lines, vapor lines, pipe, flanges and fittings as well as miscellaneous forged and cast parts. According to recent surveys covering a number of refineries, they are lasting from five to ten times as long as plain carbon steel in cracking furnace tubes, depending upon the operating conditions. This relatively long service indicates that there is without doubt a place for lower-priced steels of even lower chromium content, and somewhat less durability.

Steels for service at elevated temperatures are evaluated on the basis of corrosion resistance, oxidation resistance, lack of brittleness caused by heat or corrosion, and high-temperature loading characteristics. No one ferrous alloy possesses all these qualities in highest degree, although each of the low alloy steels has some desirable combination of qualities to recommend it for use within proper limitations. In view of the large number of authoritative data now available in the literature, a correlation of the pertinent facts about the low chromium alloy steel would seem to be helpful in appraising the compositions containing 1 to 6% chromium from the standpoint of suitability for oil refinery work. The effectiveness of chromium in reducing corrosion by petroleum products is the main reason for stressing the significance of this element in this discussion. While the part chromium plays in improving oxidation resistance and creep strength is recognized, these functions are shared with other elements which are present with chromium in the more complex alloy steels.

Resistance to Oil Corrosion

Corrosion rates of various low carbon, plain chromium steels tested under actual refinery operating conditions are shown in the first diagram on the next page. According to the data, quite small amounts of chromium cause a pronounced decrease in the rate of corrosion. This is especially true of the steels containing less than 2% chromium, which have comparatively greater corrosion resistance in proportion to the chromium present than alloys of higher chro-

mium content. Between 3 and 10% chromium the corrosion rate curve is a straight line, indicating that protection against corrosion in this range is proportional to the amount of chromium in the steel. As the price of the steels increases



Relation of Corrosion Rate and Chromium Content of Steels When Handling Certain Corrosive Crudes at High Temperature and Pressure. (Reproduced from E. S. Dixon's chapter in The Book of Stainless Steels, 2nd Edition, p. 584)

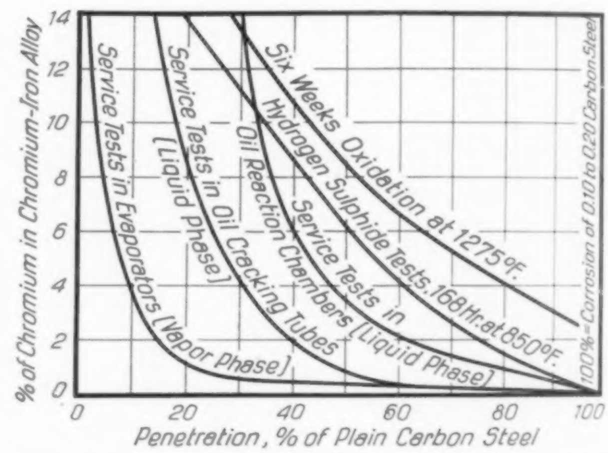
with the chromium content, the most economical steel for any application where corrosion is a factor would be ascertained from the initial cost of the installation and the length of service anticipated.

Confirming evidence on the corrosion resistance of the plain chromium steels in several classes of refinery service is given in the second diagram. These curves exhibit the same trend as the first graph, the decrease in rate of attack being again most marked for additions of chromium up to 2 or 3%.

Metallic elements such as tungsten, molybdenum, silicon and titanium may also be found with chromium in the more highly alloyed steels. The corrosion resistance of chromium steels is increased moderately by additions of titanium, since it forms a titanium carbide, which releases a certain amount of chromium for commensurate enrichment of the ferrite. However, from the information available the other alloying elements do not seem to affect the oil corrosion resistance of the steels significantly. Until more information is obtained, no great error can result from assuming that the corrosion resistance of the various chromium alloy steels is due to the chromium alone, as represented in these two diagrams. The original 4 to 6% chromium steel was a composition arbitrarily selected some years ago to satisfy the need for an economical tube material. For many applications this analysis may still be the best choice, but there are also situations in which an intermediate steel containing 2 or 3% chromium would provide sufficient corrosion resistance.

Oxidation Resistance

Oxidation resistance of a series of chromium-iron alloys is shown in the second diagram for an exposure of six weeks at 1275° F. Apart from the impression conveyed regarding the scale loss in relation to the oxidation of plain carbon steel, the most noteworthy feature of the curve is the almost linear relationship between oxidation resistance and chromium content. Of particular interest is the portion of the curve up to 6% chromium, since it covers the range of potentially useful lower chromium alloys to which attention is now being directed.



Service and Laboratory Tests on the Corrosion of a Series of 15 Iron-Chromium Steels. Service tests were conducted in ten different refineries and the rates were averaged. (Reproduced from E. C. Wright's chapter in The Book of Stainless Steels, 2nd Edition, p. 240)

Tungsten, molybdenum, silicon, and titanium are all known to affect the oxidation resistance of chromium steels to which they are added. A summary statement concerning the specific influence of these elements on the oxidation of steel is therefore relevant.

From 1000-hr. oxidation tests at 1200° F. it was found that 1% tungsten increased the oxidation resistance of 4 to 6% chromium steel about one-fifth, and 0.50% molybdenum reduced the oxidation resistance by the same amount. These findings have also been supported by the service records of the chromium steel tubes containing tungsten and molybdenum in cracking furnaces.

Silicon increases the oxidation resistance of plain carbon and alloy steels. A sufficient quan-

tity of this element alone will protect simple steels from serious oxidation up to 1200 to 1250° F. By bringing silicon and chromium together in proper combination a number of compositions have been developed which possess amazing resistance to oxidation at 1300° F. and higher temperatures. In these alloys the silicon may be regarded as a substitute for chromium as far as oxidation resistance is concerned. A steel containing 2.75% chromium and 2.75% silicon, for example, has the same oxidation resistance at 1500° F. as a steel having 5.00% chromium and 1.25% silicon. The "chromium equivalent" of silicon increases with the amount of chromium in the steel, being large for high chromium and small for low chromium contents. It is estimated that for 1 to 2% chromium in the steel, silicon and chromium are equally effective in reducing oxidation; for 2 to 5% chromium the "chromium equivalent" of silicon is about 1.5.

Titanium has been observed to increase the oxidation resistance of 5 to 6% chromium steel in tests at 1380° F. The improvement is ascribed partly to the tightly adhering scale which is formed and partly to a more favorable distribution of chromium in solid solution (resulting from the displacement of chromium by titanium in the carbides).

Toughness of Notched Bars

Absence of brittleness — in whatever form it may be manifested — is one of the first requisites of steels for high temperature service in oil refineries. This means that a steel must be initially tough at room temperature, retain good shock resistance at the operating temperature, and not become brittle upon cooling to atmospheric temperature after long heating in service. "Tensile brittleness" at elevated temperatures, characterized by sudden rupture of the metal without appreciable plastic deformation, is likewise detrimental, since tubing under pressure may fail without the swelling or bulging that serves as a warning against continued use of an unsafe tube.

Few steels are disqualified for high temperature service because of these shortcomings, although precautions have to be taken in handling some of the compositions to avoid circumstances conducive to brittleness. The low carbon, low alloy steels do not exhibit tensile brittleness and have ample impact strength at room temperature in the annealed condition. A number of pearlitic alloy steels show a minimum impact resistance when tested at 900 to 1000° F. but even the lowest values appear to be satisfactory for most purposes in oil refineries.

Plain chromium, chromium-silicon and chromium-tungsten steels are susceptible to temper embrittlement after heating in service. Molybdenum steels on the contrary are not susceptible, about 0.50% being effective in eliminating the temper brittleness of 5% chromium steel. This is shown in the table below on this page. This is the main reason for the growing preference for the 4 to 6% chromium steel with molybdenum over the same steel without the addition of molybdenum.

Large amounts of silicon may cause grain growth with attendant loss of shock resistance. Therefore silicon should always be accompanied by sufficient carbide-forming elements, such as chromium, manganese and molybdenum, to restrict the grain growth tendency and stabilize the microstructure.

Titanium is added to the 4 to 6% Cr and 4 to 6% Cr-Mo steels primarily to prevent air hardening. As secondary benefits the gain in corrosion and oxidation resistance have already been mentioned. It should be recognized, however, that when the optimum ratio of titanium to carbon content has been exceeded, the uncombined titanium in solid solution may promote grain growth and lead to a microstructural condition possessing lower toughness.

Proper proportion of titanium to carbon for given amounts of carbon in the chromium or chromium-molybdenum steel and the effects of different amounts of residual titanium in the steel have not been definitely established as yet.

Effect of 0.50% Mo on 4 to 6% Cr Steel, Annealed at 1550°F.

Steel	Treatment After Anneal	Izod Value (average of 6)	Brinell Hardness	Susceptibility Ratio
A, 0% Mo	1400°F. temper, water cool	96.5	137 to 143	1.000 (basis)
B, 0.50% Mo		101.0	143 to 149	1.000 (basis)
A, 0% Mo	1400°F. temper, air cool	95.5	132 to 137	0.989
B, 0.50% Mo		101.5	143	1.005
A, 0% Mo	1400°F. temper, furnace cool	53.0	137	0.555
B, 0.50% Mo		99.5	137 to 143	0.985

Strength at High Temperatures

The "short time tensile properties" of low alloy steels at temperatures below 1000° F. are governed to a great extent by the room temperature properties and the condition of the original structure (whether heat treated, cold worked or whatever). Increase in carbon content, the addition of special elements, and the use of heat treatments may enhance the short time strength of the steels within this temperature range. Only a few elements are capable of strengthening steels at temperatures between 1000° F. and 1200° F., and the difference in short time loading capacity of the various low alloy compositions becomes progressively smaller. Beyond 1100° F. the strengthening effects of different preliminary heat treatments begin to diminish, because spheroidization of carbides is accelerated at the higher temperatures and all the microstructures approach the same stable physical condition. Unless accidental overheating or overloading might be anticipated, creep strength is a better criterion of loading capacity above 1000° F. than the short time tensile strength, since steels under stress flow or creep continuously at these temperatures.

A study of the specific effect of various alloys on oil corrosion, scaling, toughness, and creep strength has developed a pair of low alloy steels containing silicon, chromium, and molybdenum for service in oil refineries. They are intermediate in price between plain carbon tubes and the 4 to 6% chromium tubes with 0.50% molybdenum

Creep of low alloy steels at elevated temperatures can be retarded by alloying elements such as molybdenum, tungsten, vanadium, manganese and chromium. Experiments conducted on several types of steel, in which variations in composition were confined to one alloying element, have proven that the greatest gain in creep strength usually results from a comparatively small but definite addition of each alloying element. When the maximum economical benefit has been derived from the addition of a single element, further increase of creep strength can be obtained by the introduction of other alloying elements. In this manner excellent resistance to creep has been developed in steels of low total alloy content. The most desirable combination of elements to produce a given creep strength would be determined by the cost of making the steel and the effect of the alloying elements on the other characteristics of the steel.

Molybdenum is the most powerful element in raising the creep strength of steels, especially at temperatures above 1000° F.; small additions effect a remarkable increase, and at moderate cost. One per cent is approximately the economical limit in unalloyed or low alloy steels, because the increased cost of making larger additions is not reflected in proportionate increase in creep strength. Tungsten and vanadium improve the creep strength of steels in the range from 800 to 1200° F., but the cost of adding enough of these expensive elements to produce a desired result is often prohibitive. Manganese and chromium also raise the creep strength of simple steels, though less effectually than molybdenum, tungsten, and vanadium. Maximum creep resistance is obtained with 1.00 to 1.50% manganese and 0.75 to 1.25% chromium, depending upon the type of steel. The influence of chromium on the creep strength of a series of low carbon, low alloy steels with 0.50% molybdenum is evident from the following data, wherein the figures are regarded as the limiting unit stress for the rate of creep designated (1% per 100,000 hr.). Figures are not available to indicate that either titanium or silicon changes the creep, appreciably, at temperatures higher than 1000° F.

Creep Strength of Low Alloy Steels at 1000° F.

Composition	1% Creep in 100,000 Hr.
0.15 C	2,700 psi.
0.15 C, 0.50 Mo	10,700
0.15 C, 0.75 Si, 1.25 Cr, 0.50 Mo	15,000
0.15 C, 0.75 Si, 2.50 Cr, 0.50 Mo	5,500
0.10 C, 0.40 Si, 5.00 Cr, 0.50 Mo	7,000

New Alloys Recently Developed

On summarizing the economic value of the different alloying elements in low alloy steels, it is obvious to those acquainted with the costs of the operations and the raw materials that significant quantities of tungsten, vanadium and titanium cannot be incorporated in low priced steels. Manganese does not contribute to corrosion or oxidation resistance and is of minor importance in building up creep strength at 1000° F. Silicon, chromium and molybdenum, on the

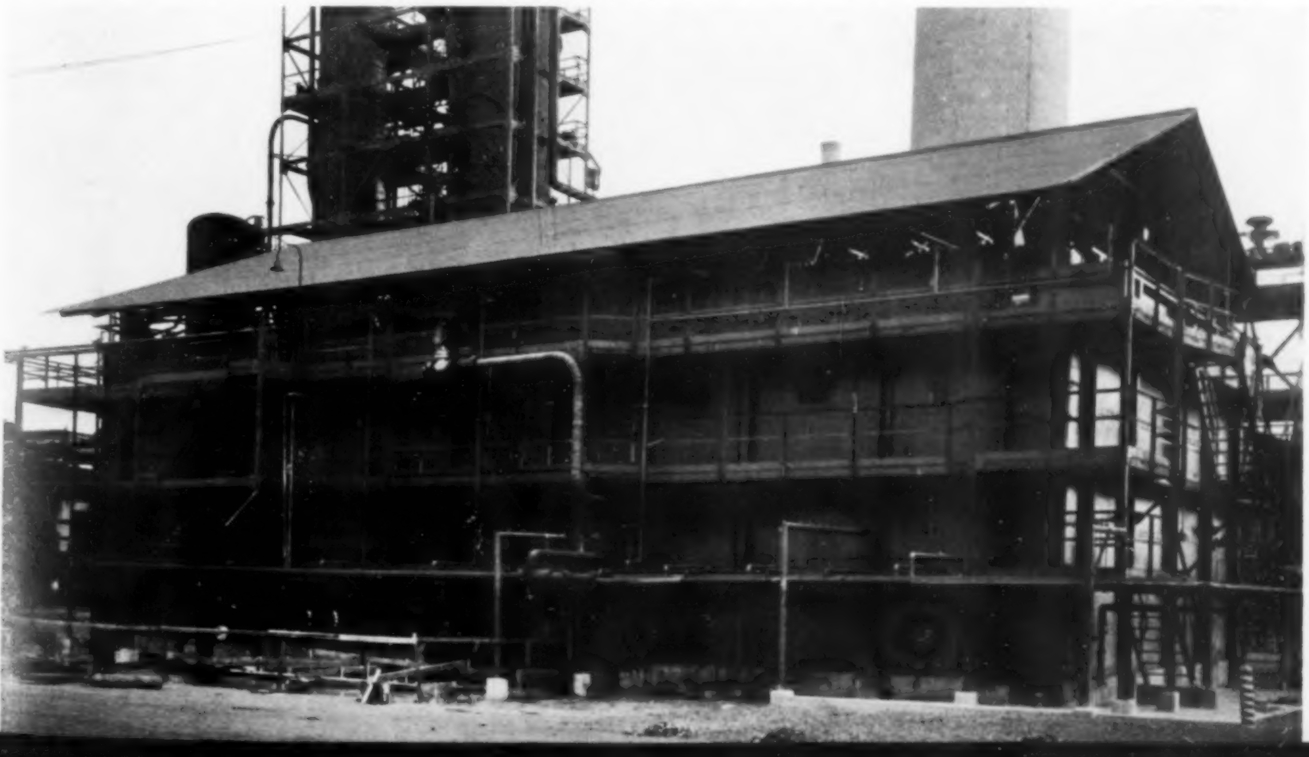
other hand, are clearly elements which can be added to steels in various combinations to produce comparatively inexpensive alloys capable of satisfying many service requirements in oil refineries. The principal function of silicon in such compositions would be to furnish oxidation resistance, chromium the corrosion resistance, and molybdenum the toughness and creep strength.

Two types of low alloy steels capitalizing the use of silicon, chromium, and molybdenum are now available to fill the need for materials intermediate in price between the plain carbon and 4 to 6% chromium steels. The first of these steels, an electric furnace alloy containing a maximum of 0.15% carbon, an average of 0.75% silicon, 1.25% chromium and 0.50% molybdenum, is characterized by having exceptionally high creep strength in the temperature range 1000 to 1200° F. Two to three times the corrosion and oxidation resistance of carbon steel is being obtained with this alloy, based on nearly three years' service in refineries. The steel does not air harden, nor become "temper brittle," and is intended for application in parts requiring high strength where corrosion and oxidation are not unduly severe. In the form of tubing this analysis costs about half as much as 4 to 6% Cr-Mo steel (which is also an electric furnace product).

The second steel intermediate in price is an electric furnace composition having 0.15% max. carbon, 0.75 silicon on the average, 2.50% chromium and 0.50% molybdenum. On the basis of laboratory and oil refinery corrosion tests, it is predicted that this steel will last about half as long as the 4 to 6% Cr-Mo analysis in corrosive still tube service, while its oxidation resistance and creep strength are of the same order as for the older analysis. (Not enough time has elapsed since the introduction of the new steel to permit citations from service records.) This alloy is not "temper brittle," but it does air harden and would have to be welded with the same care as the higher chromium steels. This Si-Cr-Mo analysis, containing 2.50% chromium, is proposed for applications where the use of the 4 to 6% chromium steels is not warranted, but the corrosion is too severe for the first mentioned Si-Cr-Mo steel of lower chromium content. The material in tube form is priced at a nominal advance over the Si-Cr-Mo steel with 1.25% chromium.

Successful applications of these low-alloy steels in oil refineries involve a critical analysis of service requirements so that installations can be made that combine economy and safety with adequate life of equipment. In selecting steels for specific applications, a thorough knowledge of service requirements is just as important as an understanding of the qualifications of the steels. This is best illustrated in the case of cracking furnace tubes, which are subjected to the extreme in corrosion, heat and pressure. Before deciding upon a suitable steel for such a service the corrosiveness of the crude oil, the furnace temperature, heat input, rate of coking, operating pressure, and firing conditions should be taken into account. Observation of the different banks and rows of tubes in a furnace may also reveal that tubes in certain positions are corroded or heated more severely than others. Data of this kind are essential in the selective application of several steels in the same furnace, each according to the varying requirements of the situation. In fact, the most dependable guide in choosing one steel to replace another is the service record and history of tube failures which prompted consideration of a better material.

One of the Largest Cracking Furnaces in the World. Designed and built by M. W. Kellogg Co. for Atlantic Refining Co., Philadelphia. 41x82x23 ft. high, firing fronts on both sides, 20 burners. Tubes 5 in. outside diameter, ⅝-in. wall, mostly 40 ft. long. Tube temperature in operation 500° F. to 1100° F.



Edited from notes for a speech to the New York Chapter, A.S.M., Jan. 1935

by Ernest L. Robinson
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Schenectady, N. Y.

Stability of steels under stress up to 1000° F.

(as viewed by a turbine designer)

MODERN STEAM TURBINES are subjecting materials to stress under temperatures of 750 to 1000° F. This is a range of temperatures in which the physical properties of steel are subject to rapid changes with temperature and the effectiveness and permanency of various heat treatments differ. Although we know a number of very useful facts and relations, when all is said they amount to very little in comparison with what we would like to know about the stability at these moderately high temperatures.

Steels hold their strength up to about 750° F. and then weaken more or less rapidly at higher temperatures. (This effect varies in magnitude, depending upon the alloys.) In fact, steels generally have increased tensile strength for a range of temperatures well above room temperature. Ductility is likely to be improved at rising temperatures except for the region of increased tensile strength, and fatigue strength or ability to resist repeated bending stress may be as high at 1000° F. as at room temperature. On the other hand, the ability to resist distortion and maintain shape (the so-called creep strength) falls off rather definitely above 750° F. and at 1000° is likely to be only $\frac{1}{4}$ to $\frac{1}{10}$ as strong. (Above 1000° F. temperature I offer no facts.)

It is well understood that the tensile test, as made in a few minutes in the ordinary way, is no indication of creep strength. It is not so well understood — and please note this — that an alloy steel which distorts rapidly during the first 1000 hr. (and 1000 hr. is just six weeks) may stiffen up in subsequent months and prove much superior at the end of a year! In other words, steel A, which is stronger than steel B to resist a creep rate of 1% per 1000 hr., is not necessarily stronger to resist a rate of 1% per 100,000 hr.

Speaking of rates — rates are very important. It is said that minute amounts of creep occur under stress at ordinary temperatures, but the amount is almost immeasurably small. A creep rate of 1% per 10,000 hr. is the same as one-millionth of the length per hr. I really think the latter is a better way to say it, because our attention is then, as always, focused on the present hour. Thus, I would rather say "one ten-millionth of the length per hr." than "1% per 100,000 hr."

When I hear someone say "1% *in* 100,000 hr.," I do not know what he means, for 100,000 hr. is eleven years and I do not think anybody has run any creep tests that long. As I shall explain by and by, a rate of 1% *per* 100,000 hr. may be attained by any one of many different loadings according to the amount of strain which has already occurred, but only one definite load could produce a total creep of 1% at the end of 100,000 hr. or eleven years. This amount can only be guessed at, but the many possible loadings for the corresponding rate may be found by tests of short duration — and this fact unfortunately leads to many arguments.

We turbine designers think of creep distortions as beginning to have importance at temperatures above 750° F. We know it is possible to measure distortion in parts which have been long under stress at temperatures above 500° F., but the amounts are minute and the determining factor is the physical strength to resist rupture. At some higher temperature the ability to resist distortion and maintain shape becomes more important than any possible danger of rupture. Where the dividing line comes depends upon the application.

Several approximate relations have been derived from our creep tests between 750 and 1000° F., and please remember these refer only to this range of temperature and small amounts of distortion. I am not referring to distortions as large as 1% or 2% (which might be all right in properly shaped pipes or superheater tubes). We cannot think of anything like that in high speed machines — at most, 1 or 2 mils per in. is permissible — so I am referring to distortions measured in tenths of a mil per in., say from 100 to 1000 millionths of an inch per inch.

Approximate Relations

Roughly speaking (and the ratios vary for different alloys) each 20° F. doubles the rapidity of creep, and a 200° F. increase of temperature is enough to accelerate the rate of distortion as much as 1000 to 1.

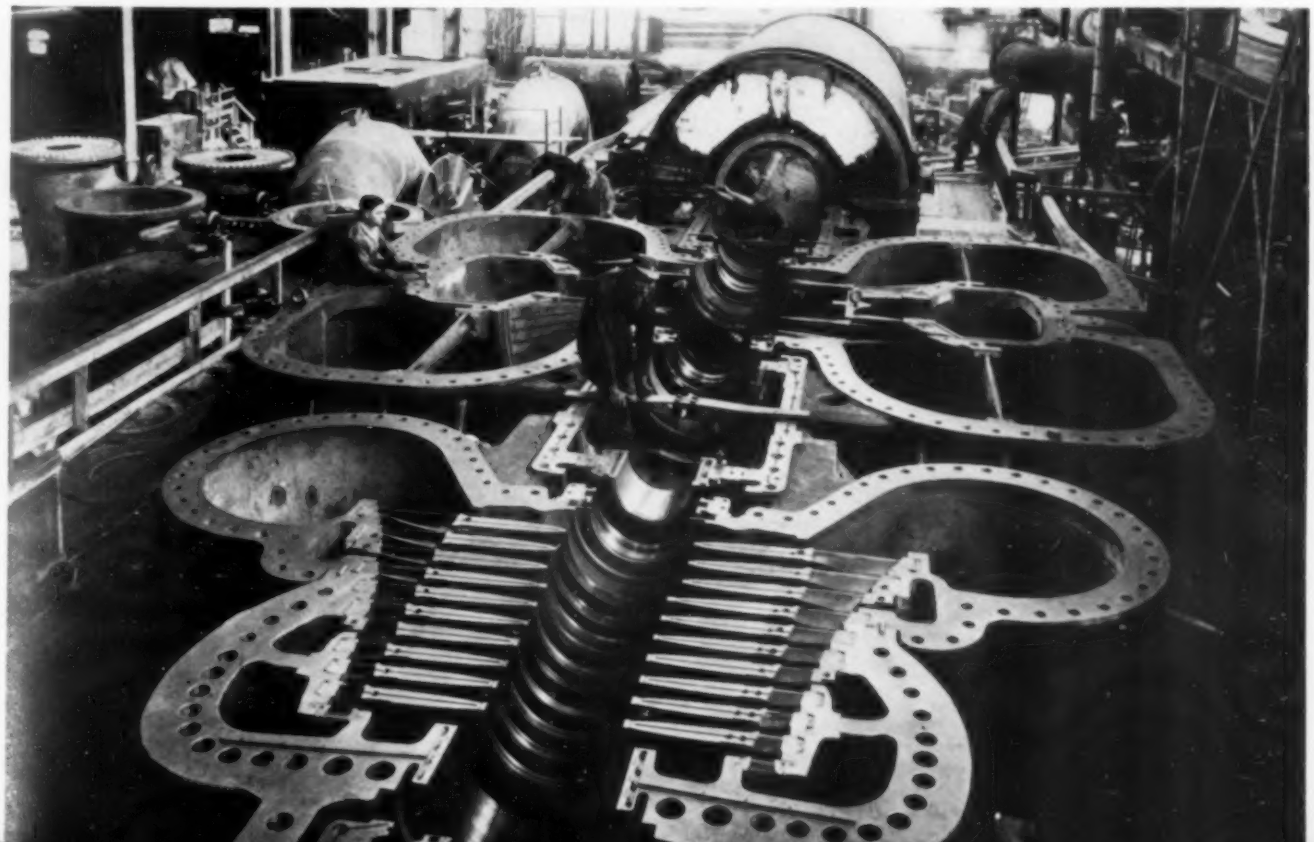
Again, if you apply 50% more stress, you will multiply the rate of distortion by 10. Conversely a reduction of stress to two-thirds will reduce the rate of distortion to $\frac{1}{10}$ its previous value.

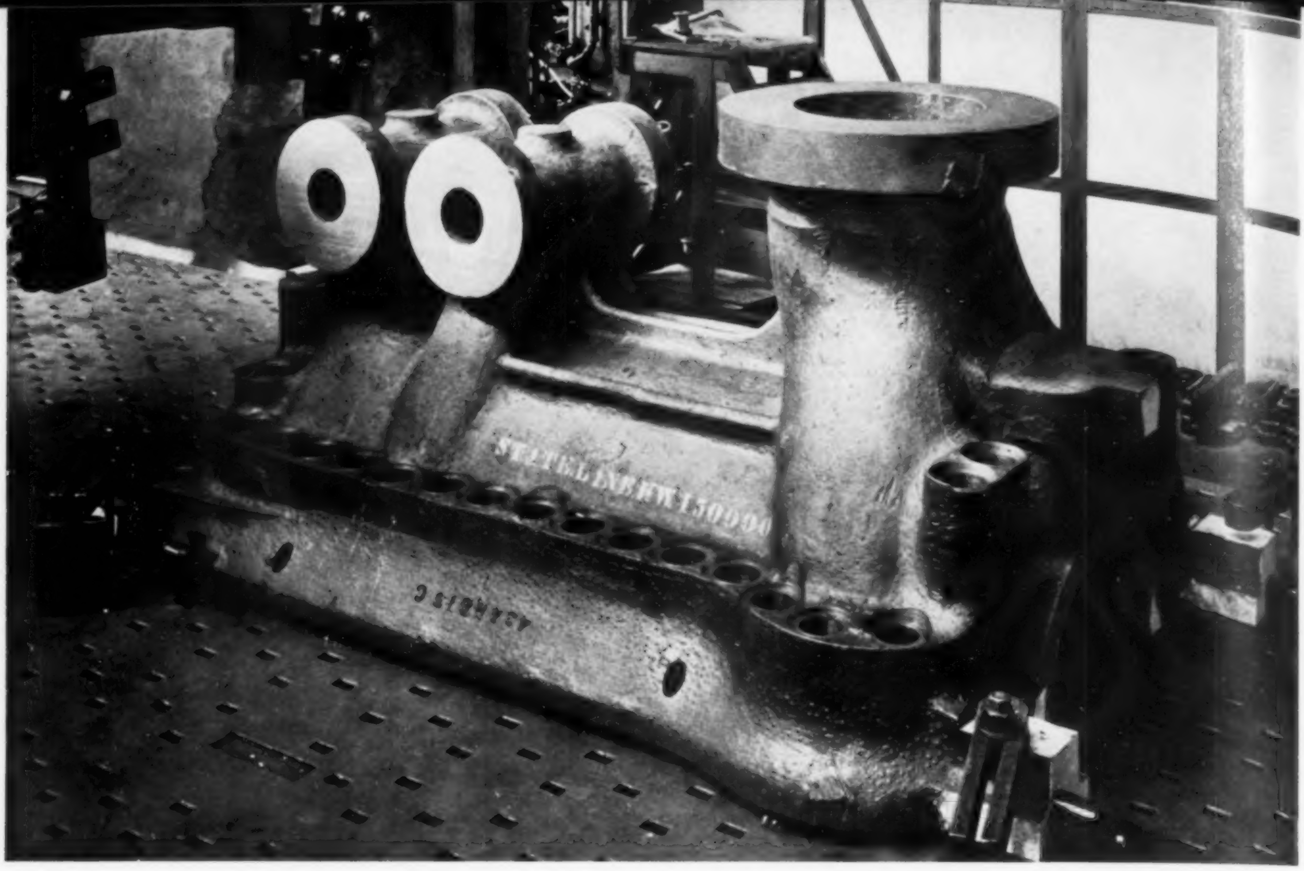
Increasing the temperature 1° F. causes a reduction of something like 1% in the creep strength of the steel, or an increase in the rate of distortion of, say, 5% of its former value.

One last generalization: During the first 50 or 100 millionths of an inch creep, the rate will be more than ten times as fast as at the end of 500 or 1000 millionths of an inch per inch total creep. Thus, a ten-fold accumulation of total creep so strengthens the steel that it will carry double the stress at a specified rate of creep. Facts such as this make it difficult for the designer, for he really should not think of his allowable working stresses at 800 or 900° F. as if they were associated with fixed and unchanging rates of creep.

Such progressive strengthening may be called "cold working," but this sounds funny, since it takes place at nearly 1000° F. — not very cold! "Strain hardening" sounds better, but

At Left Page Is a General Electric Turbine Rotor Showing Bucketed Wheels Assembled on the Shaft. Below shows diaphragms assembled in intermediate and low pressure elements of 105,000-kw. tandem compound steam turbine





High Temperature High Pressure Shell for 150,000-Kw. Tandem Compound Steam Turbine, Showing Substantial Bolting Flanges. In operation these casings are under constant hoop stress and very little plastic flow is permissible

surely we may properly say that metal at these moderate temperatures and loaded moderately is "in the range of initial flow," and that the "secondary rate" (if there truly is such a thing) has not yet been established. For the time being we are not interested in what the steel might do at higher temperatures or if you let it stretch so much that our turbines would go out of business. It may be all right to talk secondary flow rates if the equipment you are building can stand enough distortion to establish a secondary rate. My impression is that at 750 to 1000° F. no true secondary rate is ever established short of 1 to 3% total creep, whereas in turbines we cannot tolerate plastic distortions of more than a couple of mils per inch (less than 0.25%).

It may occur to you that I am referring to materials that have not been fully "stabilized." I am not sure just what that means but I believe the allegation is true. Let's talk this over for a few minutes. Whereas one would select a heat treated, fine grained steel for high elastic limit and high working stress at atmospheric temperature, it is reasonable to suppose (and some experimental evidence bears us out) that at some higher temperature a coarse, granular steel will have a better creep strength, and this is likely to be an annealed material with rather second-rate tensile properties.

Doubtless there is some temperature where the mortar and the stone, the fine material and the coarse — or, as you perhaps say, the intergranular cement and the crystals — are equally strong. Below this temperature we prefer fine grained material and above it we prefer coarse grained material. I suspect that this particular critical region is just about the same as the range we are talking about, 750 to 1000° F. Certainly we have many excellent materials which have good physical properties and good creep resistance, and the hope of improved creep strength as time goes on. So if we plead guilty to using materials which are not fully "stabilized," we shall at the same time maintain that we are using the best compromise that our judgment offers.

And this is all the more reason why we cannot tell in a short time what is surely going to happen in a long time!

Something should now be said about the uses to which we will put the steel and the functioning of machine parts at high temperature. These factors must be borne in mind in selecting the steel, the test procedure, and the means by which we reduce test results to significant numbers which express quality. In steam turbines the creep rates must be so limited that total deformation over years of service, including "initial creep" effects, will not exceed 1/5 of 1% and in many parts not over 1/20 of 1%.

Applications to Turbines

In a turbine the steam is delivered at high temperature and pressure in a number of high

speed jets against concave buckets attached to the rim of the first stage wheel or disk. The impulse turns the wheel and transmits power to the main shaft to which it is attached. After the first wheel, the steam passes through a series of nozzles in the second stage diaphragm and impinges upon the buckets of a second wheel, and so on from stage to stage until the expansive energy in the steam has been converted into work at the main shaft and the cool vapor exhausts into a condenser.

A 15-stage rotor, with wheels and intermediate packing sleeves assembled on the shaft, is shown on page 34. Each wheel is subjected to high temperature, and drives, through radial pins in its hub, a size-and-size bushing keyed to the shaft. The whole structure is shrunk upon the shaft so that the maximum stress is a hoop tension at the bore of the wheel, and it is an assembly stress induced by the action of shrinking on the main shaft. At running speed a large fraction of this hoop stress is sustained by the centrifugal pulls from the buckets and wheel rim, but unless the bore stress in the wheel is in excess of the tensions necessary to meet the centrifugal pulls, the wheel will fail to cling tightly to the shaft and ride the bushing pins. Here the condition of creep is one of plastic flow replacing elastic extension, and the total amount of such plastic flow over a period of years must not exceed the 20th or 30th part of 1%.

(I hope I am making it plain why it is necessary to know about the initial stages of plastic flow and why we cannot always judge of the suitability of materials by tests made at steady stress under loadings causing several per cent total stretch.)

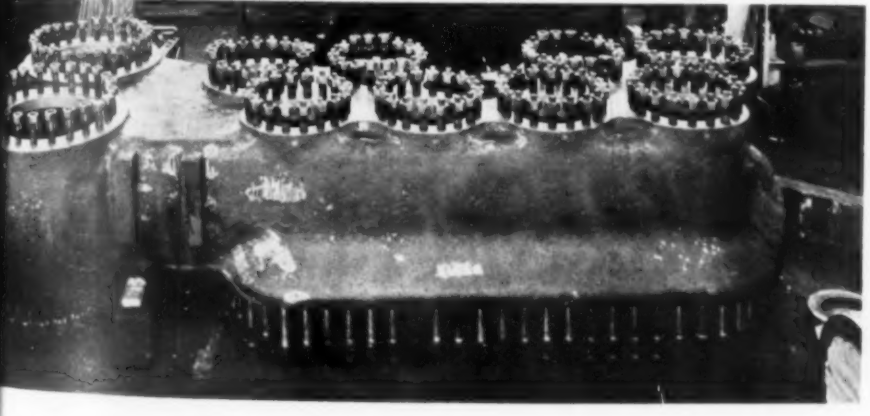
Before leaving this subject, note that the bushing ring must cling to the shaft through thick and thin. Then there is a whole series of interstage packing bushings and it is important that steam does not leak under them, for any steam leaking from stage to stage is supposed to traverse the tortuous path of the labyrinth teeth. The centrifugal effect on initial stress in interstage bushings is small, and a larger fraction of plastic relief is tolerable; but again please note that we are dealing with the suppression of stress relief rather than with the inhibition of large deformations.

Lower shells of intermediate and low pressure stages of a very large (105,000 kw.) turbine are shown in the view on page 35. In the foreground ten diaphragms may be seen in place. They simply divide the shell into the stage compartments which have successively lower pressures as the steam goes through the turbine. Stresses in diaphragms are essentially bending stresses, but shear and torsion are present. Although differing considerably from what goes on in a straight creep test at constant stress, there is this similarity — that the condition of stress is sustained, and if the material is not of high enough creep strength the diaphragm will eventually slump enough to rub against the rapidly rotating wheel.

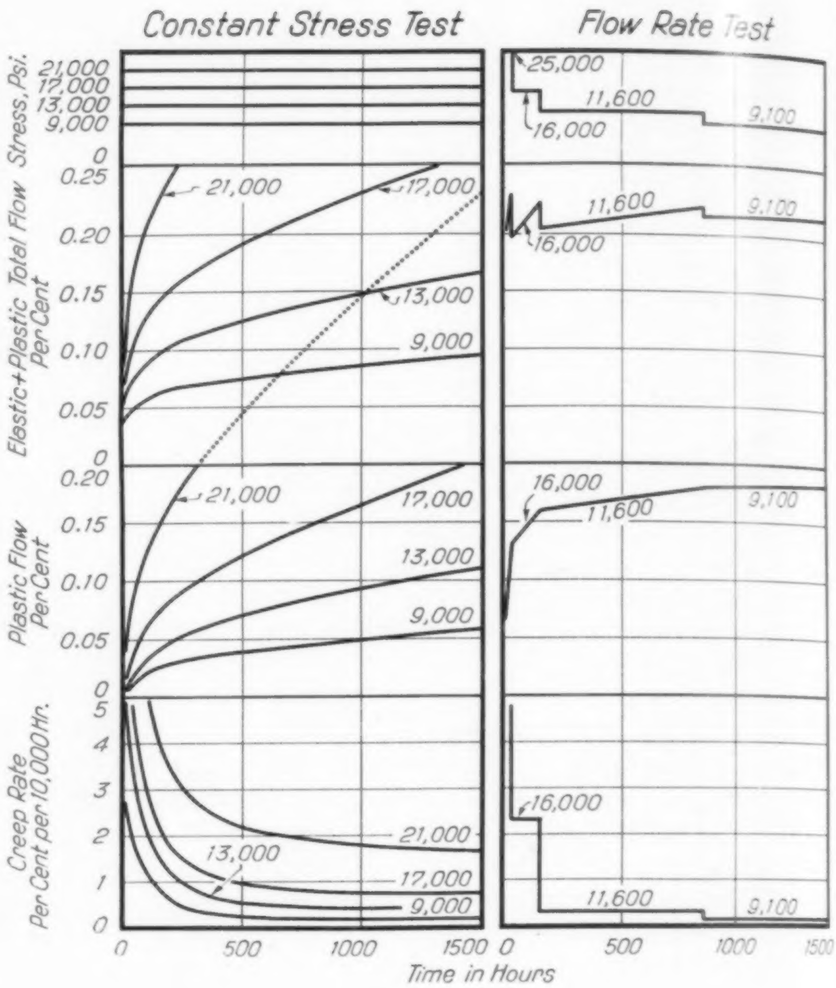
The shell or casing shown on the opposite page is the main stationary element of the machine. Please note the substantial flanges and the bolt holes. These shells are bathed on their inside surface with superheated steam, and the stresses are essentially tensional bursting stresses. However, the casing is split horizontally for convenience of assembly and servicing, so we have flanges with certain local regions of bending and compression. Tension in the shell is caused by the internal pressure confined, and this depends only on the loads carried by the turbine. As long as the machine is subjected to regular load schedules, it is subjected to regular stresses. There is no relief with time. Plastic enlargement continues. Although the condition of stress differs from that in a simple tension test, the service corresponds to the conditions present in the so-called "constant stress creep test."

Numerous and rugged bolts hold the upper and lower halves of these shells together and prevent steam leakage. These bolts are set up to an initial tension much higher than corresponds to the steam pressure, giving rise to the local contact pressures

The Numerous Studs in This Valve Casing Emphasize the Importance of Creep Strength Under Controlled Conditions of Limited Relaxation

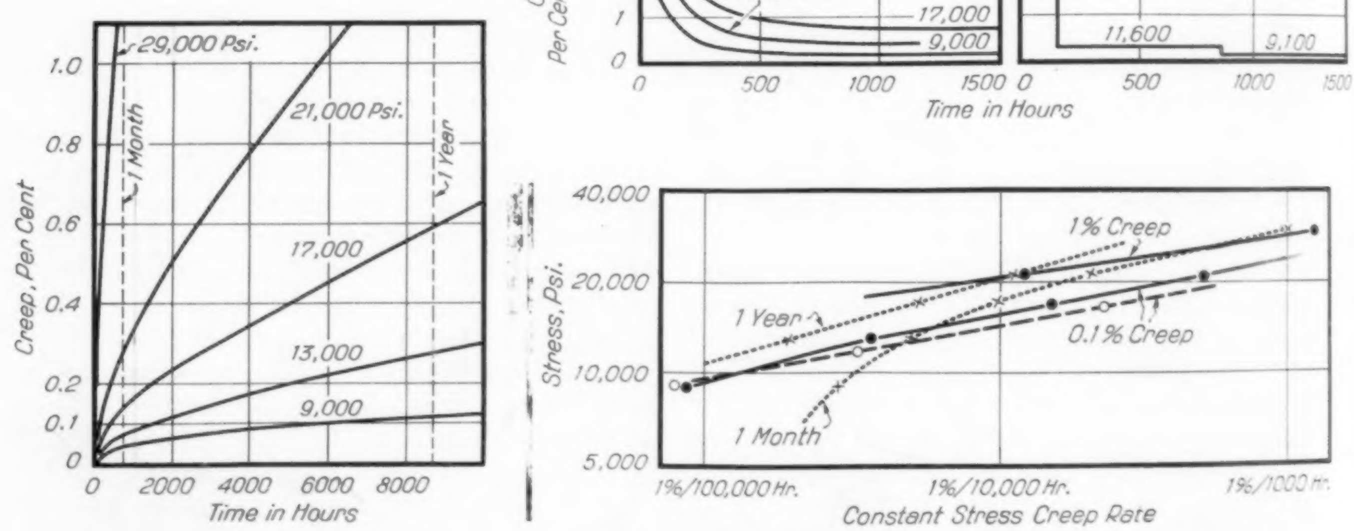


At Right Are Two Diagrams Comparing Results of Constant Stress Test on Four Bars and Flow Rate Test on a Single Bar When Strain (Elastic Plus Plastic) Is Held as Constant as Possible Near 0.22%



at the flanges. In this case the tension in the bolts is not sustained as time goes on; creep replaces corresponding elastic elongations and permits gradual relief of the initial tension. If such relief goes too far — if the material creeps too rapidly — there will be steam leakage and that cannot be tolerated.

The photograph on page 37 of a valve casing should convince the observer that bolting is really important. In these bolts, as in those between shell sections, the total elastic plus plastic strain is constant, and the total permissible creep is but a fraction of the elastic strain — that is, 1/30 to 1/20 of 1%. The only mitigating circumstance is



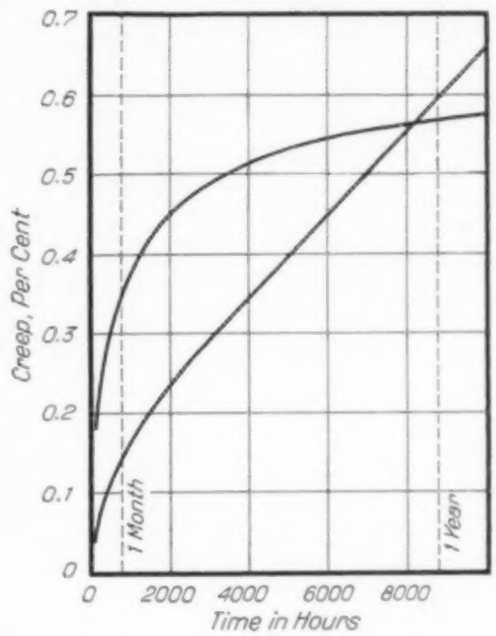
Constant Stress Tests Were Continued for 10,000 Hr. and Plotted in Two Ways. Note that there are two legitimate families of lines on the log-log plot showing the relation between the slope of the creep curve and the applied stress, namely, the dotted lines each taken at the end of a specified time, and the full lines each taken after a specified amount of total creep has occurred in the steel

that bolts may be tightened, but bolts that have to be tightened all the time are not doing the job expected of them.

Turning now to methods of creep testing, and passing over the automatic test equipment we have had in operation for several years (for it has already been described elsewhere), let us look at some of the typical strain-time curves — particularly those determined at constant stress and those where the stress is stepped down at intervals (the latter known as a "flow rate" test).

The two kinds of tests are shown at the top of the page. At the left you see what happens when we make a constant stress test. A series of stresses are specified. They may correspond to the loading of a shell or a pipe or, less closely, of a diaphragm. For each we plot the total strain, elastic plus plastic, or the total creep excluding

elastic strain, and then get a creep rate as shown at the bottom. After what seems like a long time (and to some people 100 hr. is a long time, to others 500 or 1000 hr., and to still others 10,000 hr.) we note that the rates are not changing very fast and we say that each such rate is caused by its specified stress. From the series we plot a log-log curve of rate vs. stress and we announce the "creep strength," which in reality is often a figure based on a relatively few hours of testing.



A Comparison of Time-Creep Curves of Two Different Materials at Two Different Temperatures Shows the Difficulty of Generalization as to Performance at Some Far Distant Time

At the right you see what happens when we make what is called a flow rate test. Using a single specimen at successively reduced stresses gives us conditions approximating the specified total elastic plus plastic strain of a bolt, wheel or bushing, as described above. Total strain — elastic plus plastic — is maintained nearly constant by stepping down the stress and taking off elastic stretch as plastic flow occurs. Also the total creep curve flattens more rapidly, because of the reduced stress, and there is a more definite knee. Furthermore the rate curve at the bottom is also definitely flatter.

Here, obviously, are two ways of associating a creep rate with a stress. Can either of them be interpreted to mean that the material has a definite creep strength? I am inclined to pay less attention to the first, for it is based on a rather haphazard choice of what is thought to be a long time, and from what I learn from discussions with metallurgists, *time* is of lesser significance at these moderate temperatures.

The second, on the other hand, is based on a specified total strain depending on design use, and what I hear about cold working and strain hardening leads me to believe that this is an extremely important auxiliary attribute to keep track of.

The same creep curves were continued on to 10,000 hr. (14 months) and are shown at the left of the lower figure, page 38. The bars under test are 3/8 in. diameter, 5 ft. long (gage length 20 in. in a 30-in. heated portion at 857° F.). Steel was previously annealed at 1500° F. Its composition is carbon 0.37%, manganese 0.55%, silicon 0.16%, nickel 1.78%, chromium 0.77%, molybdenum 0.36%.

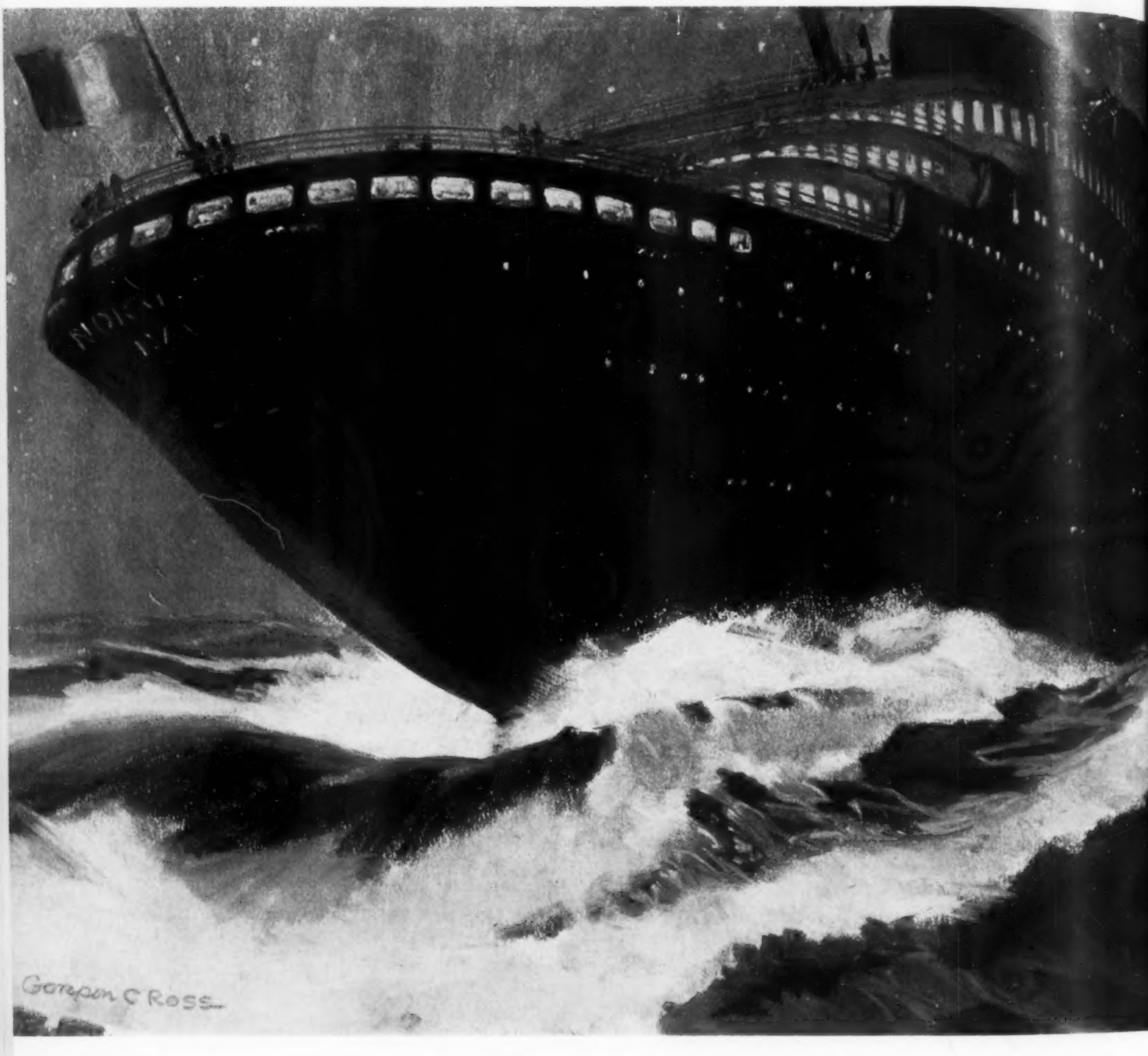
On the right of that figure is the familiar log-log plot of stress vs. rate. On each diagram there are two pairs of lines: *(a)* A pair of time lines showing the state of affairs at the end of a month and again at the end of a year, and *(b)* a pair of creep lines showing the state of affairs with $\frac{1}{10}$ of 1% extension and again at the end of a full 1% extension. The times may or may not be significant; probably they are very short as compared with the life of the apparatus. The creep lines, on the other hand, represent the relation between stress and rate for specified strains of 1 mil per in. and of 1%, and one of these may be your allowable strain.

Whatever stress is chosen from the stress vs. rate diagram and set down to represent the creep strength of the material will obviously be an arbitrary or "nominal" strength. If you choose a rate from a short time test at low stress and put down the corresponding stress after a month, you are not taking advantage of allowable strain hardening — while if you put down a stress corresponding to a rate at high stress after a year, you may be taking credit for strain hardening which could never be tolerated in service. That is indeed a choice for the designer to ponder over!

Please note the open circle line closely following the $\frac{1}{10}$% line in the log-log plot. That was made from the flow rate test on an extra bar in the same multiple-bar furnace at the same time and under the same conditions as the five others on this diagram. Does it matter which line is used for the relation between stress and rate for $\frac{1}{10}$% creep? Apparently the result obtained from the fourteen months' test on five bars is pretty closely reproduced by the two months' flow-rate test on one bar.

It may be that the idea of quoting a stress for a certain rate was originally based on the idea that the rate would "stay put." Maybe it is all right to go on that basis when you are using

(Continued on page 78)



"It is interesting to look at this great ship from the metals point of view, since there are many present day developments in metallurgy without which the Normandie could not have been built."—C. H. Jansson, Editor Marine Review.

DRAWING KINDLY LOANED BY SOCONY-VACUUM OIL COMPANY

by Marjorie Rud Hyslop
Secretary to the Editor
Metal Progress

Strong and fine metals used on the Normandie

THE MUCH PUBLICIZED, record breaking trip of the liner Normandie on her maiden voyage across the Atlantic has served to familiarize most of us with the general features of this largest ship now in commission. The choice of steels and alloys should therefore be of interest for a 1029-ft. hull, which, stood on end, would overtop an 85-floor skyscraper — for electrical propulsion equipment which provides power sufficient to light the city of Boston — and for the most sumptuous and modern of cabin fittings and decoration.

Weight saving being of less importance than in a battleship, the greater part of the 30,000-ton hull is constructed of ordinary open-hearth steel of 60,000 to 64,000 psi. tensile strength. (Plates for the boiler drums are somewhat softer, with a tensile strength of 57,000 to 60,000 psi.) Nevertheless, 6400 tons of high tensile carbon steel were used for such highly stressed parts as bottom plating, tank tops, keelsons, sheer strakes, and main strength decks, and for life boat davits and cradles where weight must be kept low. Properties of this steel, as specified by the French Bureau Veritas, are 82,000 to 85,000 psi. tensile strength and 16% elongation.

Many exceptionally large and heavy steel castings make up parts of the stem — the stern frame, for instance, is made in two parts, the larger piece weighing over 74 tons. The four shaft brackets weigh 172 tons. The rudder itself is a cast steel frame covered with steel plates and weighs 96 tons. The 47-ton rudder stock was forged from vanadium steel. These heavy parts were made by the Skoda Steel Works.

The two forward and one aft anchors are 16 and 12-ton forgings, respectively, and are housed inside the main lines of the hull. The 180 tons of anchor chain are 4 and 3¾ in. diameter and have 450 and 350 tons breaking strength respectively — 50% higher than the regulation requirements for anchor chain.

The Normandie's four propellers are of cast manganese bronze. Their design was the result of three years' work with scale models in a testing tank, wherein 12 designs of three and four blades were studied. Particular care was taken to shape the blades so as to transmit the maximum power at 240 r.p.m., to have good efficiency when engines are reversed, and to avoid cavitation or partial vacuum at working speeds (with its attendant vibration, noise, and damage to the blades). A three bladed design was finally adopted. Measuring 16 ft. in diameter and weighing 23 tons each, they required great skill in the foundry. Construction of a mold required 15,000 bricks, 20 tons of sand, and 30 tons of steel, and occupied six weeks. Pouring required several hours, metal being added at intervals to counteract contraction, and ten days were allowed for cooling. In the shops the boss was faced and bored, keyways were cut, and the blades trimmed to required pitch and dimensions, ground, polished, and finally balanced so accurately that they could be moved by one finger. A complete set was made for spares.

Although welding was extensively used in steel fabrication and assembly, over 11,000,000 rivets are in the ship's hull. Principal applications of welding to the structure were for columns, bulkheads, stiffeners, stairways, water tanks, elevator shafts, and machinery pedestals.

Electric propulsion is standard for ships of largest size. Careful study was required to decide whether the propeller shafts should be geared to the steam turbines, or whether turbines should drive an electric generator and the power used in motors, direct connected to the propeller shafts. Four complete power plants, one for each propeller, and each developing 40,000 hp., were finally installed by Société Als-Thom of Belfort, General Electric Co. acting as consultants.

Geared turbines were judged to be less bulky and weighty, and slightly more efficient, over all, but these advantages were more than counterbalanced by the entire absence of vibration in the turbo-electric drive, but especially because the propellers can be reversed full speed in a few seconds in emergency by throwing an electric switch. This enables the captain to stop the 80,000-ton Normandie from full speed ahead in three ship-lengths!

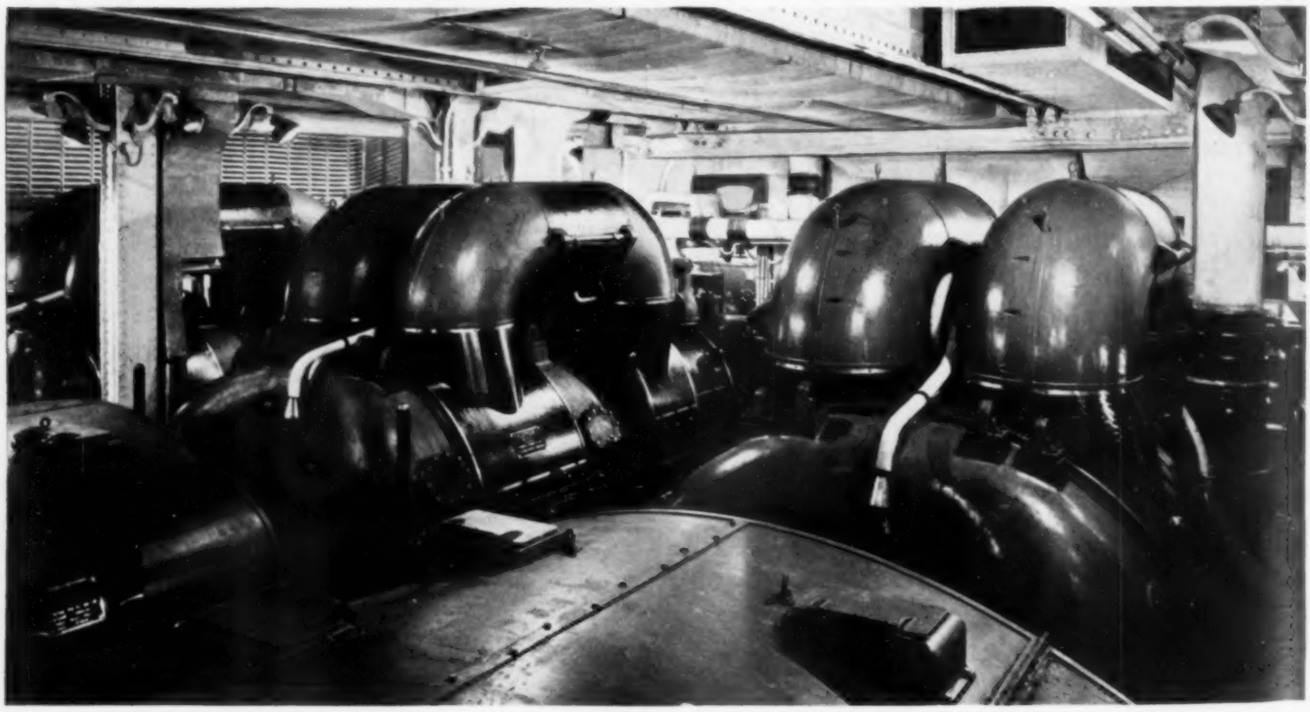
Steam is furnished at a pressure of 400 psi. and a temperature of 680° F. by 29 oil-fired boilers of the water tube type. High pressure pipe flanges are screwed on and then welded; gaskets are sheets of scored soft iron. The main boilers supply four turbo-alternators, developing in all 160,000 hp. at 2430 r.p.m. Generators and motors are cooled by circulating sea water.

Main turbines are two stage; the high pressure casing has 13 wheels and the low pressure casing, of double flow design, has three wheels in each compartment. Turbine disks are of nickel-chromium steel treated to 99,500 psi. tensile strength, 78,200 psi. yield point, and 14% elongation. Blades and runners are of an alloy known as "ATV" (the initials of *Alliage pour Turbines à Vapeur)* originated by Pierre Chevenard at Imphy laboratories and developed especially for turbine blades by Commentry-Fourchambault et Decaseville. Average composition and physicals are quoted as follows:

Nickel	35%
Chromium	11%
Carbon	0.30%

Tensile strength	88,000 psi.
Yield strength	45,500 psi.
Elongation	20%
Brinell hardness	156 to 187

This material is resistant to corrosion by salt water and superheated steam regardless of its surface polish, retains good physical properties at superheated steam temperatures, resists erosion, is easy to fabricate and weld, and, being an



Four 40,000-Hp. Turbo-Generators Are Side by Side Athwart Ship. One is out of the view at right. Top of generator casings shown in lower foreground, low pressure turbine casing just beyond with duplicate steam mains from high pressure stages at far end

austenitic alloy, is independent of heat treatment.

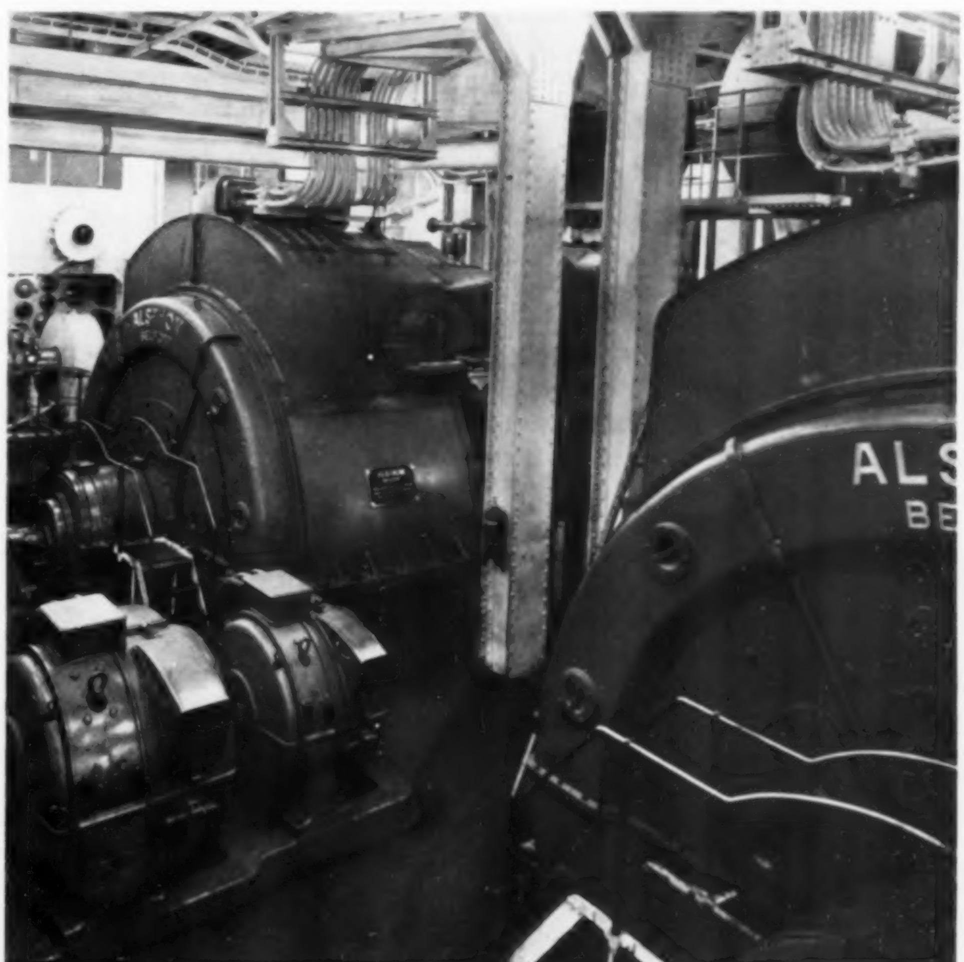
Various other strong steels and alloys are used in the engine room. A 2% nickel steel with chromium and molybdenum has excellent mechanical characteristics at the temperatures to which the bolts and nuts of the steam headers and intake ports of the turbines are exposed. In the annealed state it has 78,200 psi. tensile strength, 50,000 psi. yield strength, and 20% elongation. Monel metal, "ATV," and special cupro-nickels containing tin or tin and silicon for high heat resistance are used for steam valves and cocks. A 5% nickel steel is employed in the expansion joints and steam headers.

Requirements of the 40,000-hp. motors are for high mechanical properties to transmit so much power at the slow speed of 243 r.p.m. Shafts are of a nickel-chromium steel containing 2.70% nickel, 0.70% chromium, and 0.15% carbon, and developing 85,300 psi. tensile strength, 50,000 psi. yield, 15% elongation longitudinally and 12% transversely. Couplings are of a slightly higher carbon steel (nickel 2.50 to 3.00%, chromium 0.60 to 0.80%, and carbon 0.20 to 0.35%) which after heat treatment shows 121,000 to 135,000 psi. tensile strength, 99,500 to 114,000 psi. yield, and 12 to 15% elongation.

The ship also has six 2200-kw. turbo-dynamos furnishing 220-volt direct current for lights, small motors, and manifold uses of electric heat and power. The dynamos have an iron shell and are cooled like the generators and alternating current motors. These small steam turbines also have ATV blades, and the shafts and couplings are of the nickel-chromium steel described above. Their condensers are built with cupro-nickel tubes (70% copper, 30% nickel). This alloy has been found most durable, particularly for condensers working in contaminated water while in port. (See Metal Progress, July, 1933, for a description of this copper-nickel alloy.)

Eight rotary pumps, turbine driven, have stainless steel turbine blades and shrouding and monel metal pump impellers and diffusers.

Some interesting applications of metal have been made in the electric wiring. High tension cables (5400 volt) for the main drive are made of high conductivity copper wire, coiled over a hemp core, insulated by layers of oiled linen and rubber and armored by mattresses of tarred jute and spirally wound bronze ribbon. All insulation is designed to avoid absorption of water, either at ordinary or steam temperatures. Main cables carrying power for the multitudinous services throughout the ship are armored with lead and galvanized steel wire or galvanized sheet steel. Secondary cables in gangways, and exposed cables generally, are sheathed with lead hardened with 2% tin to make it rat proof. Wires



Two of the Four Main Motors, Direct Connected to Propeller Shafts. Small auxiliary generator at left foreground is on centerline of ship. Power plant photographs courtesy Socony-Vacuum Oil Co.

in all public rooms and first-class cabins are laid in metal conduits — a channel with a removable cover — either concealed or worked into the design as a part of the decoration.

Kitchens on the Normandie gleam with polished nickel, stainless steel, and other non-tarnishing alloys. Pure nickel is used for coffee makers, milk and chocolate heaters, and other cafeteria equipment. Five huge steam kettles are of nickel. Tops of warming tables (the one in the first class kitchen is 56 ft. long) are of 18-8 stainless steel, as are many of the pots and pans and other kitchen implements. Refrigerator cases are of monel metal.

Most unusual has been the use of metal and glass in decorating the ship and in the cabin furnishings. Since the furnishings represent 10% of the total $53,000,000 cost of the ship, an atmosphere of luxury prevails throughout.

Most striking is the extensive use of the 18% chromium, 8% nickel stainless steel — about 95 tons altogether. It enters into all types of hardware, bathroom fittings, lighting fixtures, furniture, door handles, baseboards, and general decorative trim. Handrails consumed 2 miles of stainless tubing. The name of the ship appears on the bow in stainless steel letters approximately 3 ft. high. Stainless steel window frames, fabricated by Edward G. Budd Co., Philadelphia, were used in the "winter garden," which is glass enclosed on three sides and exposed to spray from heavy seas. Considerable cushioning has been necessary to suppress noises from slightly loosened glass.

Specifications called for this material in the wrought condition only, the engineers being unconvinced that castings could be produced free from all pitting and defects. Many cast parts, as well as a good deal of hardware, are therefore of nickel "silver." Sixty tons of the type containing 60% copper, 18% nickel, 22% zinc were used.

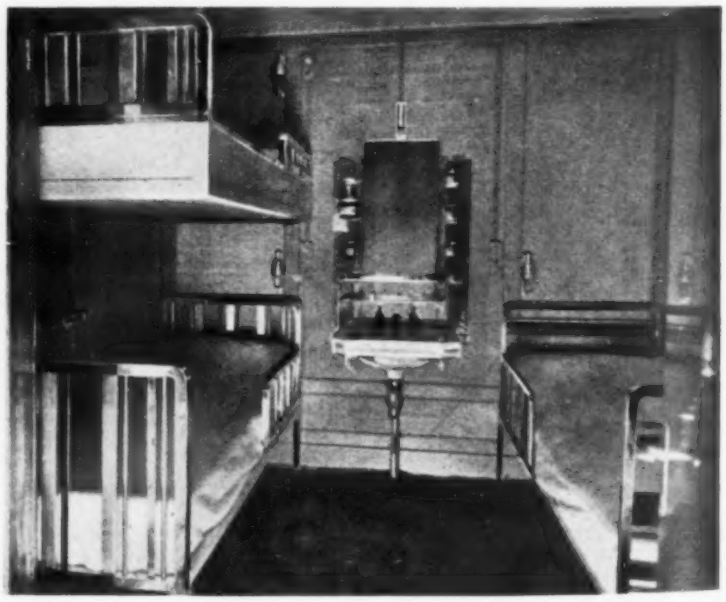
It is interesting to note that nickel and chromium plate are practically nonexistent on the Normandie because of their poor record in resisting sea water and sea air corrosion.

The framework and much of the sheathing of the main halls and dining-rooms have been made of steel, to avoid the concentration of combustible material in such places. Metal is sometimes enameled in beautiful design but usually lacquered with a special material which has a high kindling temperature and when overheated gives off a minimum of dense smoke. Monumental doors in the main dining-room are of gilt bronze, ornamented with medallions representing scenes in various Norman towns. Decorative panels of onyx and cast glass are set off by hand-wrought copper, with gilded or oxidized finish.

The cafe grill, oval in plan, and located at the after part of the boat deck, has glass walls set in stainless steel framing. All of the chairs, tables and incidental furniture in this room are on stainless steel frames. The grill itself (of non-corrosive alloys) has a decorative cast iron panel behind and above it.

Some of the luxe and first-class cabins are built entirely of light alloys — architectural trim, furniture, and wardrobes. All furniture in the crew's quarters, third-class and tourist cabins (a large majority of all in the ship, in fact) is of metal, grained and lacquered. Some few of the tourist cabins are done in stainless. All other furniture has been fireproofed.

In order to reduce the fire hazard pressed cork, rubber products, and impregnated cellulose are used for all floor coverings, hangings, and fabrics. An interesting feature connected with the fire protection system is small metal portholes in the ceiling of over 1300 cabins and closed spaces, through which the crew can thrust a hose nozzle, so that a fire inside can be flooded without opening any door and letting any air into the conflagration.



Tourist Cabin on the Normandie. All furniture in such cabins is on metal frames — some, as the one illustrated, are done in stainless

Notes on some books worth reading

Elements of Steel Treating

HEAT TREATMENT AND METALLOGRAPHY OF STEEL; Elements of Physical Metallurgy, by Horace C. Knerr. Second Edition, 161 pages, printed one side only. Loose leaf, 8½x11 in., bound in flexible fabricoid. Published by the author, Philadelphia. Price $3.50.

Mindful of the fact that it is dangerous to say that Mr. Doe was the *first* to do a certain thing (for somebody will be sure to point out that Mr. Roe did the same thing several years, generations, or even centuries previous) this reviewer will merely point out that the Philadelphia Chapter of the A.S.M. — then "Steel Treaters" — organized evening courses in metallography in Temple University as early as the fall of 1923. These have continued without interruption ever since, thus pointing the way for the many educational courses given elsewhere in recent years.

The man who has carried the brunt of the work in Philadelphia is Horace C. Knerr. In 1923 he was metallurgist in the Naval Aircraft Factory. Not content with holding down this job and teaching evening classes, he proceeded to write this textbook in elementary metallurgy and metallography. It ran serially in *Forging and Heat Treating;* the supply of reprints having been exhausted by some 600 students in subsequent years, the text is reproduced by photo-offset process in present loose-leaf form.

It is curious that men do some of their very best work when hard pressed for time to do it. The present book would be a real undertaking for a man with some leisure — perhaps that is why the leisured individual seldom gets busy on an important creation. The fact that the author is content to duplicate it without extensive revision is proof that it has served its pedagogical purpose excellently.

In such writing and lecturing as this, the problem always is "What shall I present, of all the mass of material available; what is essential to the subject; what can be eliminated?" Mr. Knerr has evidently decided to give his classes a very broad view, for he includes steel mill operations, optical theory of microscopes, practical pyrometry and furnace design. Probably some of these are included principally for reference, for these subjects when added to thermal analysis, metallography of steel, heat treatment operations, theory of hardening, and properties of the alloy steels, make up a study course seemingly too comprehensive for a single year in night school.

It is too bad that the offset process of printing, while excellent for text, is atrocious for halftones, so many of the illustrations in the book leave much to the imagination. In his preface the author apologizes for not having the time for a more thorough revision — the reviewer finds the only notable deficiency so caused is in the section on alloy steels. Changes in the last ten years have been great in the carburizing steels and process, the carbon steels with controlled grain size, S.A.E. steels containing molybdenum, and the stainless steels. These developments, however, have not greatly changed our understanding of the fundamentals, which occupy 90% of Mr. Knerr's valuable text.

A Master Teaches

METALLURGICAL DIALOGUE, by Albert Sauveur. 166 pages, $5\frac{1}{2}$ x 8 in., 12 portrait plates. American Society for Metals, Cleveland. Price $3.

Professor Sauveur in Metallurgical Dialogue has adopted an unusual mode of presenting rather profound ideas. Through the easy informality of a conversation between "master" and "pupil," much of the content of physical metallurgy is considered deftly, with a light touch, and with a generous sprinkling of the dry humor which is his delightful characteristic.

The book, however, is more than a mere review. It contains within its covers statements of theory and fact that represent original contributions. More important, it is autobiographical, inasmuch as it pictures a teacher who is really the author and gives an intimate view of Sauveur the teacher.

The answers of the master to the simple questions of the student often represent final conclusions based on years of study, but they are stated without confusing details of experimental evidence or of logical deduction. This treatment is necessarily somewhat dogmatic — no one but a Master could present a subject in this way. Sauveur is a Master. His statements carry weight because of his recognized sincerity and conservatism, and because of the unusual respect accorded to one who for more than forty years has been a molder of metallurgical thought throughout the civilized world.

To appreciate the book, one must appreciate the man. His scholastic training was obtained at Liége in Belgium and at Massachusetts Institute of Technology. Following his formal education he spent ten years in the steel plants of the Pennsylvania Steel Co. and the Illinois Steel Co. He has taught and has directed research at Harvard since 1899.

Sorby, in England, was the first to use the microscope to study metals. Some twenty years later, Martens in Germany, independently of Sorby, and Osmond in France (probably influenced by Sorby and Martens) were among the small group of the earliest pioneers of the metallographic method. In 1893, while Sorby was still active, Martens, Osmond and Sauveur all presented papers on the subject at the International Engineering Congress held in Chicago. Sauveur's paper was a pioneer effort to point the way to metallographic control of heat treatments. He was always working in the front line of progress — witness two doctorate dissertations, presented by his students in 1935, which were advanced studies in the physics of metals.

Although his original training was essentially chemical, he has seen metals as physical bodies. Largely through the influence of his teaching, metallurgists think of steel in terms of metallographic structures. *Structure* is the important thing; methods of control involve various questions of physico-chemical equilibria and mechanical working. Chemical composition is important but even this is secondary to physical structure.

The physical theory of metals has been developed mostly from evidence afforded by the microscope. Professor Sauveur has seen the theory develop from the beginning to its present state — which is about as far as the microscope can carry it. Additions to theory are still being made from microscopic studies, but any great advances from this source must await improved optical equipment, and patient men to use it.

Consequently, X-ray diffraction studies have been responsible for recent advances in theory. The interest in the use of X-rays in investigations of metal structures is growing, and Professor Sauveur has been keenly alive to the possibilities of this new research tool. One of his students has made very important contributions in the field. However, the application of X-rays to studies of metals ushers in a new phase of metallography. Its development will be in the hands of a new generation.

It would be impossible to estimate the direct and indirect influence of this man. Through his students, through addresses, through published papers, through personal contacts with industry, and perhaps most importantly through the influence of his best known publication — The Metallography and Heat Treatment of Iron and Steel — his ideas have permeated the metals industry and have become so deeply imbedded in metallurgical processes that in many cases their origin has been forgotten.

In point of time his active career has covered the development of physical metallurgy as we know it today. He has been one of the most important contributors to this development. It is fitting that in the autumn of a distinguished career as author, teacher, and director of research he should view in retrospect the larger problems which have engaged his attention during the years that have passed. It is indeed fortunate that he has given the results of his retrospect in the form of this somewhat whimsical but exceedingly valuable little volume. H. H. LESTER

Physical Metallurgy

The Principles of Physical Metallurgy, by Gilbert E. Doan. 332 pages, 6x9 in., 240 illustrations. McGraw-Hill Book Co., New York. Price $3.

In 1933 Professor Doan collaborated with D. M. Liddell in writing "The Principles of Metallurgy." This book was reviewed in Metal Progress in January, 1934, and it was there noted that Mr. Liddell's portion of the book was confined to what might be called chemical metallurgy, and Professor Doan's to physical metallurgy. The present volume is merely his portion of the larger book, slightly expanded in certain places, and remains "a unique and up-to-the-minute summary of the whole new science of physical metallurgy" (to quote the earlier review). "The book can be recommended unreservedly to any man whose mind is still in the inquisitive stage."

Some may object to the large number of references to German sources. They should remember that we in America pay all too little attention to work that is going on abroad, and frequently rediscover and broadcast new facts our overseas cousins have known a long time.

The Phase Rule

Principles of Phase Diagrams, by J. S. Marsh. 193 pages, 6x9 in., 180 figures. One of the monograph series of the Alloys of Iron Research. McGraw-Hill Book Co., New York. Price $3.

To the average metallurgist (and probably to the average chemist and physicist) Willard Gibbs' phase rule

$$f = c + 2 - p$$

is one of those rare but terrifying generalizations like "God is good," which pack into a single statement the sum total of human experience. He therefore concludes that a finite mind cannot comprehend its manifold implications in finite time, and so is thankful for others who have applied themselves seriously to reason it out.

To the average metallurgist that is probably all right. He can regard the binary structural diagrams as approximate pictures of what should exist in his commercial alloys at various temperatures, and in case of doubt verify the indications by specific tests. Unfortunately they give little indication of the effect of third elements, and few indeed are commercial steels and alloys that do not contain disturbing quantities of a third, and even a fourth or a fifth.

Members of the Alloys of Iron Research — who, as will be remembered, are reviewing the literature of alloy steels — soon found that "ternary diagrams would be largely undecipherable unless a key were provided." This book is an attempt to provide that key. It is not a simple key, that if lost can be replaced with a buttonhook — it is more like one to open a safety deposit vault. So it in turn requires intense study.

The first third of the book is given over to a statement of the fundamentals of thermodynamics and a derivation of the phase rule from such conceptions. Thirty pages suffice to illustrate the possible binary systems, so the bulk of the book devotes itself to the ternaries. The next generation will doubtless advance to a new edition emphasizing quaternaries, which in this book are only mentioned.

An interesting new system of nomenclature, devised by O. R. Spies of the Alloys of Iron Research staff, is proposed on page 95. Binary alloys get along pretty well with liquidus, solidus, solvus, eutectic, peritectic, and eutectoid, but ternaries and more grown-up systems will do better with dichortic, tricygic, tetracrystic and disteric points, lines and surfaces. (The Greeks had a word for it!)

Aluminum

Chemical Analysis of Aluminum. Methods standardized and developed by the chemists of Aluminum Co. of America under the direction of H. V. Churchill and R. W. Bridges. 83 pages, 5¼x8¼ in., paper bound. Aluminum Research Laboratories, New Kensington, Pa. Price 50¢.

The sub-title tells the story of how this book came about, and the title is slightly misleading. The methods cover all the usual (and many unusual) elements entering commercial aluminum metal and its various alloys. While a brief discussion of the historical development of the analytical methods for the element aluminum is given, no detailed procedure for gravimetric determination of *aluminum* is contained in this pamphlet. It is also pointed out that the methods have been developed for process control and specification work, and that in some instances high accuracy may be sacrificed to convenience, yet in all cases they are more accurate than the available methods of sampling.

Alloy Steels

Einführung in die Sonderstahlkunde, by Eduard Houdremont. 566 pages, 6½x9¾ in., with 577 illustrations and 138 tables of data. Published by Julius Springer, Berlin, W.9, Germany. Price 52.2 RM.

Here is a book! It excites admiration as a specimen of the printer's art, for it approaches the quality reached by German textbooks before the War, and equalled by only a few really fine printers in England and America. Its outer form matches its inner excellence.

Unfortunately too few in America have heeded their teachers' admonitions that foreign language literature can only be appreciated in the native language, and so not nearly as many of us can read the book as should for our own profit. For Dr. Houdremont has collected here his own voluminous researches and important ones in other foreign countries, organized the entire mass of material, and interpreted it in the light of experience gained by one of the pioneering plants making high grade steels (he is works manager of the Krupp plant at Essen). It is right up to the minute — a minority of the references date before 1930 and here and there even the year 1935 is noted! Hence one finds adequate statement of such things as the most recent of researches by Bain and his associates into transformation rates, the new iron-cobalt-tungsten tool alloys (age hardened), and pitting corrosion of austenitic stainless alloys.

The book can be regarded as an "introduction" to the subject only as one thinks humbly of the present state of the metallurgical art and science as being merely the threshhold of the world of knowledge. Indeed, the author assumes that his reader needs no references to the elements of the subject and plunges boldly into such theoretical matters as appropriate equilibrium diagrams at the beginning of each section.

The first 100 pages describe carbon steels both from a theoretical and practical aspect (the former leading, as always). A clear exposition of the hardening and heat treatment theory is given, together with data on the effect of various fabrication operations on the properties and structure of steels. Where else is a text to be found which has yet given much space to surface markings on deep drawn sheets, normality and hardenability of carbon steels, magnetic properties of highest purity iron, and alloying effects of the gases oxygen, nitrogen and hydrogen?

The remaining 450 pages are given up to alloy steels made by the ten principal metals and a half dozen minor metals. A list of important subdivisions of the section on manganese steels will indicate the way each is organized. First is the latest information on the iron-manganese equilibrium diagram, and then the influence of carbon on the properties of the alloys is discussed. Next the manganese tool steels are considered, including the non-shrinking steels and austenitic alloys (Hadfield's steel). Then follows a full statement of the properties of medium manganese steels, which have been used by us in great tonnage but so recently that American information about them is still confined mostly to periodical and trade literature. Lastly follows a section on the influence of manganese on the hardenability, fracture, cleanliness and physical properties of the steels that it enters, and its reactions on manufacture and fabrication.

Such treatment of each section of the entire field of alloy steels requires the widest possible range of information, and the book abounds with references to literature other than German — roughly 40% of them. This familiarity with world affairs is sadly lacking among Americans, due in no small part to the failure to heed the above-mentioned advice of our professors.

Liquefied Fuel Gases

Handbook of Butane-Propane Gases, Second Edition. Arranged and Edited by George H. Finley. 375 pages, 9x12 in. Published by Western Gas, Los Angeles, Cal. Price $5.00.

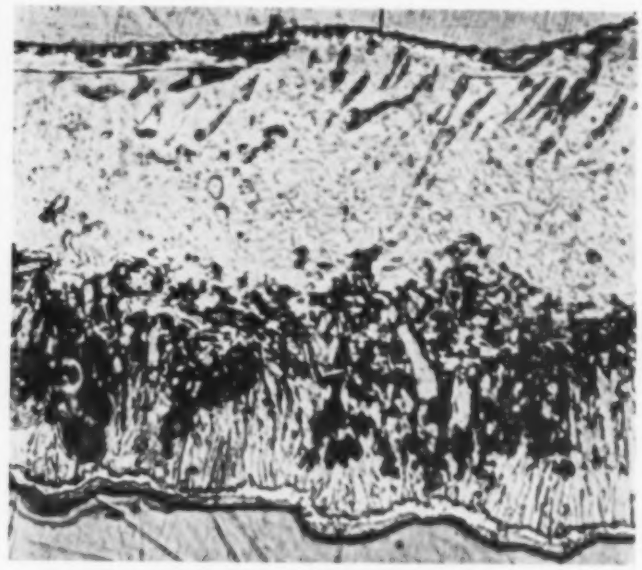
The second edition of the Handbook of Butane-Propane Gases presents authoritative data on the production, physical properties, distribution, and utilization of butane and propane gases. It is a complete revision, includes nine new chapters, and adequately treats the problems attendant to the use and recent applications of these fuels. The work is warranted in view of the increasing use of these hydrocarbons as high grade industrial fuels. Originally available as "casinghead gasoline," a condensate drawn from sumps in gas lines, it has become an important fuel with the discovery that it could be profitably recovered from the lightest gases arising from the distillation of crude petroleum.

Various factors that enter into the economics of utilizing propane and butane gases in comparison with other fuels are fully discussed. Such essential items as *(Continued on page 68)*

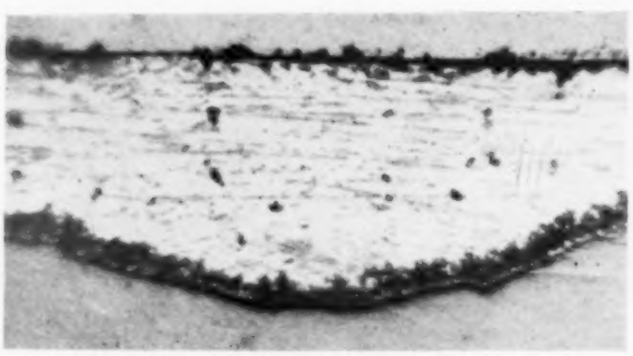
Microstructure of Galvanized Ingot Iron

All photographs at 100 diameters magnification. Gray area at bottom is ingot iron; gray area at top (of about same tone) is soft metal mounting

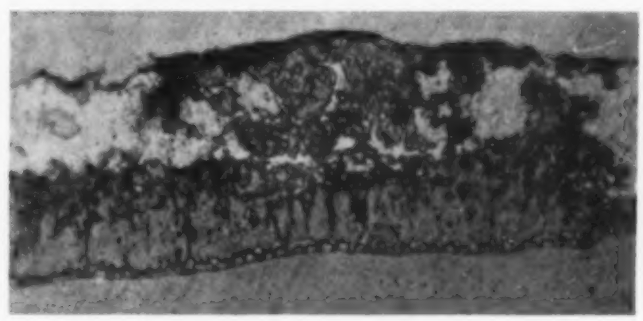
Typical of Hot Dipped Galvanized Ingot Iron. Note layer of iron-zinc alloy near base and layer of relatively pure zinc at surface



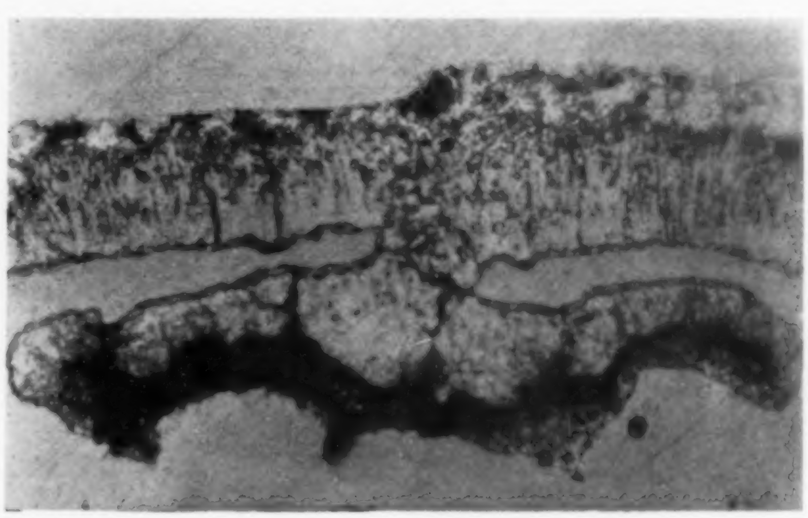
Typical of Heavy Coat Hot Dipped Galvanized Ingot Iron. Note greater thickness of the relatively pure layer of zinc at the surface



Hot Dipped Galvanized Sheet Showing a Smaller Amount of the Iron-Zinc Alloy



Hot Dipped Galvanized Sheet, Showing the Penetration of Iron-Zinc Alloy Through the Relatively Pure Zinc Layer to the Surface



An Unusual Micrograph Indicating How Molten Zinc Will Penetrate and Fill Cavities in the Surface of the Base Metal

COURTESY AMERICAN ROLLING MILL CO.

by F. Grimshaw Martin
Consulting Metallurgist
Liverpool, England

Service records of welded ships excellent

IN RECENT YEARS the applications of cutting and welding to new construction and repair work in shipyards have enormously increased. Everyone is now well accustomed to cutting out the incipient crack and welding it up. In some cases complete fractures are repaired by welding. The use of welding for gas-tight vessels, air compressors and high pressure boilers has been much extended (of course, in these circumstances the method is ideal) and has lent much confidence in the new art.

It is proposed in this article to consider briefly the applications of electric welding to shipbuilding in Great Britain, and to discuss briefly what one might describe as the alpha and omega of the all-welded ship. It was the reader's privilege to examine, metallurgically, a large number of welds made in connection with the first all-welded ship and he well remembers his astonishment at the excellence of the workmanship on that vessel.

Everybody knows that the fundamental principle underlying electric welding is that the so-called electrode supplying the metal, either to build up or make a joint, forms one terminal of an electric circuit and the object, which has either to be built up or joined up, forms the other terminal. Both the adding-to and joining-up processes have been practiced for so many years that they have been practically perfected and can be relied upon after being properly inspected — with the exception of two details.

First, in the course of construction and erection it must frequently happen that overhead welds have to be made (and this particularly applies to shipbuilding). Now a drop of molten metal at the end of an electrode obeys the laws of gravity exactly like a drop of any other liquid and as it is white hot it has to be treated with the greatest respect! This difficulty of making molten metal defy the laws of gravity under the influence of a concentrated electric and magnetic field has been very largely dealt with and eliminated by the use of special covered electrodes, but it nevertheless still has to be carefully considered in the design and erection of a ship.

The second great difficulty is equally important — that of adverse climatic conditions. While considerable portions of a ship could be built under cover and finally moved to the ship itself (the size of parts depending principally on the cranes available), a great amount of the work has to be done out in the open. It is obvious that a man will not make such a perfect job when working under such conditions as snow, rain, hail, frost, or thunder, as when fine weather prevails. This will always be a difficulty until a ship can be built entirely under cover.

The first all-welded ship was the Fullagar, which was launched from Messrs. Cammell Laird's yard at Birkenhead in February, 1920. This was built entirely with the welding process known as "quasi arc."

This vessel was built to the classification and survey of Lloyd's Register of Shipping. Previous to the construction of the vessel, exhaustive tests, lasting over a period of six months, had been

carried out on large and small examples of welded construction. These tests were so satisfactory that Lloyd's Register formulated their Tentative Regulations for the Application of Electric Arc Welding to Ship Construction. The Fullagar on completion was classed "100 A.1., electrically welded, subject to annual survey, experimental" and went into the service of her owners, Messrs. T. & J. Brocklebank, Liverpool, in July, 1920. Later she was purchased by the Manx Isles Steamship Co., and renamed Caria.

Her dimensions were as follows:

Length, between perpendiculars	150 ft.
Breadth, molded	23 ft. 9 in.
Depth, molded	11 ft. 6 in.
Depth to quarter deck	15 ft. 6 in.
Hold capacity	26,000 cu.ft.
Gross tonnage	398 tons
Speed	10 knots

Design and construction of this ship have been well described in the literature. I now propose to review her operating history, which is certainly most favorable, and lends much confidence in the welding method.

She has passed through varied and strenuous service in the coastal trade and on many occasions has been in service in very heavy weather, when other vessels of the same size have remained in port. Several times she has been aground, and on each examination later in dry-dock, the bottom plating and keel have been found to have resisted the excessive strain without any ill effects to the welded joints. On no occasion was there any leakage through the shell.

On one occasion the forward length of bilge keel on the starboard side was carried away and the welded angle lugs attaching the bilge keel to the shell were bent. The repair crew attempted to dislodge these lugs from the shell by hammering, but the result was that the heel of the lug itself fractured without disturbing the welding. A collision also caused serious indentation to the shell plating abreast the after cargo hatch; here again the welded joints remained intact, whereas in a riveted ship the rivets would probably have "started," necessitating immediate repairs.

In June, 1924, a serious accident occurred to the ship; she went aground, fully laden, on a sand bank in the Mersey during a voyage from Liverpool to Belfast. She floated off at the next high tide and, as she was perfectly water-tight, proceeded on her voyage. On arrival she was found to be damaged considerably, but as the shell was still water-tight she returned to Liverpool under her own power. On dry-docking she was thoroughly examined and by using sights the bottom was found to be set up 11 in. from bilge to bilge over a length of 70 ft. From the evidence of the inside structural work she had been set up even more, but had settled when placed on the blocks. During this time the vessel was thoroughly examined by Lloyd's surveyors, Admiralty officials, and various shipbuilders, who were much interested. The opinion was expressed that the welding had stood a most remarkable test, which was demonstrated in a highly satisfactory manner, as had she been an ordinary riveted ship, she might have been a total loss.

She then proceeded under her own power to Leith, where, after an official examination, the method of repair was decided upon. Had the ship been made with riveted plating and framing, it would have been necessary to remove unfair shell plating, the floors being faired in place, but in view of the fact that the shell plating was welded and perfectly sound, nothing had to be removed from the hull. The bottom as a whole was forced back into line by means of shores and hydraulic jacks from the deck beams. During this heroic operation the welding remained throughout perfectly sound.

As was to be expected, the 11-in. setting up of the bottom over an area of 1500 sq.ft. disturbed the frames, floors, keelson, and other members. These were partly set back and made sound and seaworthy, a few were renewed, the keelson being deepened for a portion of its length by the addition of two 8x3½-in. bulb angles placed back to back on top of the rider plates.

Welds Withstand Abuse

The welds have stood the reversal of the abnormal stresses equally with the solid plate, during the process of forcing back the excessive deformation of the plates into their original position.

This vessel, despite her many vicissitudes, is still classed A.1. at Lloyd's, and is still in such a satisfactory and seaworthy condition that permission was given for her voyage across the Atlantic, through the Panama Canal to the North Pacific Coast, where she has since been employed in carrying cement. After more than ten years' prolonged exposure of the welds to corrosive action of sea water it is impossible to trace undue corrosion of the metal in any part of the structure. It should be remembered that the work was done with an early variety of covered electrodes.

It is decidedly interesting to compare the foregoing facts concerning S.S. Fullagar with the latest all-welded vessels, Robert the Bruce and Queen Margaret. These are the first all-welded vessels to be constructed on the Clyde and are to be used as paddle ferry boats for passenger and vehicular traffic between North and South Queensferry. They are 149 ft. long by 28 ft. broad molded, by 7 ft. 10 in. deep, 47 ft. 8 in. breadth over sponsons, and 4 ft. 3 in. loaded draft.

No great attempt was made to obtain a very light structure; a ferry has to be a substantial ship and one that can stand continuous service (since there is no time for slight damage to be repaired and the ships are only surveyed once a year). Vehicles weighing up to nearly 11 tons loaded can be accepted, and all parts of the ship that are liable to sustain a heavy rolling load are designed with a reasonable margin.

THE history of the Fullagar, the first all-welded ship, is cited to show the great reliability of this method of construction and to warrant its expanding use in shipyards. The author is an authority on materials for ship construction and on cargo and storage problems and ship design.

Covered electrodes were also used exclusively throughout this work. The hull of the Robert the Bruce was constructed in large sections in the welding shed; in the interests of economy the largest possible plates were used. Intercostals, engine seat girders, and flanged floor plates were welded direct to the shell, no angle connections being used. Frames and beams are of ordinary angle section fitted toe-to-plating, and the beams were fitted in one length the entire width of the shell (where possible) which was slotted to suit. Each bulkhead was completed in the shed as one welded panel, the stiffeners being flat steel bars increased to deep angle stiffeners which were welded to plating in way of deck girders.

Deck erections were also welded in as large panels as possible. The navigating bridge was constructed in one complete section including the bulwarks, wheel house, and wing cabs. This was lifted on board after the machinery was in position, its supporting struts having been fitted previously.

The heaviest panel completed in the shed was the portion of the bottom shell containing the main engine base, the dimensions being 16 ft. 6 in. fore and aft, by 24 ft. athwart-ships. The largest panel for use as one of the completed deck sections was nearly 18 x 46 ft.

The many benefits to be obtained from completing as much work as possible in the welding sheds will be readily perceived and were so great, as climatic conditions and their attendant difficulties were eliminated, that a considerable amount of inconvenience was accepted cheerfully in view of the many other advantages gained.

The above indicates that the latest all-welded ships are about the same size as the earliest. It might also be said that deep sea trawlers — ordinarily about 160 ft. long — are practically all welded except the shell plating. A fleet of 36 such vessels was recently delivered; the builders were of the opinion that the shell could have been welded at slightly greater cost and a little extra time. These ships operate in fishing banks 2000 miles from home port, so their reliability is thoroughly established.

The above is not to infer that welding is never done on larger ships. By no means. Its extended use in the world's navies is common knowledge. In the merchant marine it is also used where some advantage in design or some economy in construction is apparent. The auxiliary advantage of water tightness and oil tightness is the ruling consideration in the welding of bulkheads, bunkers, tanks, bridge and boat decks and deck houses.

Welding might also be applied to a greater extent to ships such as oil tankers, the life of which is restricted to a great extent by corrosion troubles, and to other designs of cargo vessels — less liable to corrosion — on which dependence is largely placed on the reliability of the shell and weather deck.

In conclusion, I may state that in my opinion welding is both an excellent method of construction as applied to shipbuilding and an efficient means of repair to ships, and that most jobs effected by this process are both durable and completely satisfactory in every way. The service records of the small welded vessels are most excellent. Problems of design and erection have yet to be worked out before the all-welded big ship is launched — of these the erection problems are the most difficult, in the opinion of experienced shipbuilders.

Frederick Mark Becket

investigator - metallurgist - executive - leader

One of a series of biographical notes of eminent living metallurgists

NOTHING could be more appropriate than to include Dr. Frederick M. Becket in METAL PROGRESS' gallery of eminent living metallurgists, for he has contributed so much of importance to electrometallurgy, led so ably in the upbuilding and welfare of the metallurgical profession, and has been so honored by his associates: Perkin Medal (1924), President (1925) and Honorary Member of American Electrochemical Society, President of American Institute of Mining and Metallurgical Engineers (1933), Doctor of Science, Columbia University (1929) and Doctor of Laws, McGill University (1932).

Following graduation in 1895 from McGill and brief employment by Westinghouse, he soon had his first contact with high temperature electrochemical processes with Charles E. Acker in Jersey City, where development had just been started of the fused bath method of making caustic soda and chlorine from sodium chloride. This brought the young man in contact with problems new to his experience, and with characteristic decision he left promising commercial work to enter Columbia University for post-graduate study, receiving an A.M. in 1899, after which he returned to Acker to assist in the design and construction of a large plant at Niagara Falls.

Again feeling the need of more theoretical knowledge in physical chemistry and metallurgy, young Becket turned back to Columbia where he had opportunity to work under such remarkable men as Professor Chandler in chemistry and Professor Howe in metallurgy. In the spring of 1902 he was urged to join the Ampere Electrochemical Co. at Niagara Falls, then engaged in commercial research, and here began his first contact with commercial ferrous metallurgy on the problem (still unsolved) of producing steel direct from iron ores. In 1903 Dr. Becket helped organize the Niagara Research Laboratories, Inc., and since that time his life's work has been almost entirely devoted to electrometallurgy and steel.

While Niagara Research Laboratories devoted itself to research work, this work had to pay its own way. Equipment was frequently meager, yet the results secured with it can be compared without disadvantage to those of the modern research units of vast resources. Simply to list the problems studied and the names of those sponsoring them that crossed the threshold of this little red brick building, or the investigations that were taken up independently by the management, would be an interesting task.

Becket immediately realized the difference in value of the high carbon and the low carbon grades of ferrochromium, and tackled the problem of producing the latter. The only low carbon ferrochromium available in 1903 was the metal produced in Europe, principally by refining high carbon ferrochromium, but the fact remains that progress in alloy steels was awaiting a more economical method of production. It is significant that Niagara Research Laboratories sold its output of low carbon ferrochromium in Europe as well as in the United States.

He started in by reproducing (on a many times larger scale) the electric furnace experiments of Moissan, but the results were not economic. Early disappointments were followed by several months of intensive experimentation, in which it was determined that by carbon reduction of chrome ore and silica a chromium-iron-silicon alloy of low carbon content could be obtained, provided the percentage of silicon in the product were sufficiently high. At the same time he found that the silicon in the chromium-iron-silicon alloy would effectively reduce chromium oxide at electric furnace temperatures, giving a high chromium, low carbon, low silicon alloy.

At this juncture, Becket secured from his friend F. J. Tone of the Carborundum Co. some of the latter's metallic silicon which was also new at that time. This product was also successfully used in the production of high quality, low carbon ferrochromium. As a result of this intensive laboratory and semi-commercial work, the bulk of the low carbon ferrochromium used in the United States for more than the past 25 years has been made by the silicon reduction process. At Niagara Research Laboratories the process was also extended to the production of ferrotungsten, ferrovanadium, ferromolybdenum, and other important alloys. During this period Dr. Becket discovered another important high temperature reaction, namely, the direct reduction of refractory sulphides by silicon.

During the period 1903 to 1907, opportunity came to him to work out the production of ferrovanadium from three different classes of raw material, which were then the only sources of vanadium, namely, the vanadiferous sandstones of Colorado, the vanadium compounds extracted from Utah uranium ores used in the production of radium salts, and lastly the rich deposits of vanadium sulphide from the Andes Mountains of Peru. A detailed description of the diversified experimentation and the business dealings involved in this early work on ferrovanadium would constitute interesting history.

The first shipments of vanadium sulphide

ores to come from Peru were made to Dr. Becket for reduction (oxidized ores later being furnished) and the ferrovanadium produced from these materials enabled the American Vanadium Co. to start its development work with steel manufacturers. Dr. Becket witnessed the first heats of chrome-vanadium steel at the Homestead Works of Carnegie Steel Co., and he has told of having been present when the first heat of vanadium steel was made in the spring of 1907 at the plant of the United Alloy Steel Co., Canton, Ohio, when he had the pleasure of meeting Henry Ford and his associate, C. H. Wills, who were then much interested in this new alloy steel for important automobile parts.

In the fall of 1906 the then newly formed Electro Metallurgical Co., an affiliate of Union Carbide Co., entered the ferro-alloy field through the purchase of a plant producing high carbon ferrochromium at Kanawha Falls, W. Va., and also the Niagara Research Laboratories. Dr. Becket was made chief metallurgist and the company started construction of a large plant at Niagara Falls under his supervision. Not only had metallurgical trails to be blazed in the early days of Electro Metallurgical Co., but pioneer work in engineering had to be undertaken, chiefly of an electrical nature. Exceptionally large furnaces were installed, intensifying the old-time difficulties with power factor and electrodes.

Within three years after Electro Metallurgical Co. started operations, Becket instituted an Experimental Department, primarily for the development of new products and of more economical methods of making the several products then being manufactured. This "department" grew, and in 1921 the research facilities of some of the units of Union Carbide and Carbon Corp. were consolidated by formation of Union Carbide and Carbon Research Laboratories, Inc., of which Dr. Becket was later made president.

A study of Dr. Becket's work as represented in the patent literature shows an ever-increasing scope. New smelting processes, ferro-alloys and many combinations thereof, carbides, furnaces, electrodes, refractories, steels and welding rods are all represented in the list of more than a hundred. Considering his early experiences, it is not strange that he pioneered in several lines of activity. An example of this is his work on the high chromium-iron alloys for heat resistance and many other purposes.

It would not seem too much to say that it was a very fortunate circumstance for the ferro-alloy industry — and thus for ferrous metallurgy in general — that this man came with this particular industrial organization, since it brought a brilliant and enthusiastic scientist into a group of aggressive men willing to back research as it was backed by few others in the early years of the twentieth century.

Sometimes it is very hard to fix on paper the personality of the subject of a biographical sketch. This is particularly true in the case of Dr. Becket. The fact that he is an accomplished musician and a connoisseur of written English conveys little of his versatile intellect. That he does possess great versatility is immediately apparent to all who confer with him. An unusual charm of manner, which is at once quiet and dignified but still warm in friendliness, marks him. Probably the highest tribute which can be paid to any man by his associates is to say that he is always solicitous of the welfare of the younger men working under his direction, and this unselfish interest has been rewarded by the keen sense of personal attachment which exists for him among members of his present staff and his former associates.

It might seem that the possession of a sound technical education with an unusual mentality might serve for "easy" progress, but Dr. Becket's career has been marked by sustained effort. His long hours in the works or at his desk are proverbial. When engaged on an urgent matter it is nothing for him to work through the day and until 12, 1 or 2 the next morning for the better part of a week, reappearing on time each morning ready with new ideas.

Some of these attributes were touched upon by one of his associates, James H. Critchett, upon the occasion of the Perkin Medal award, as follows: "His one outstanding trait deserving emphasis above all others is thoroughness — the establishment of a high standard of accomplishment with the persistence to achieve it. I have never seen a piece of important work leave his hand as finished that could be improved by additional effort. In this a remarkable memory is of great help . . . . . Indeed Dr. Becket's ability and willingness to train those under him and self-sacrifice in promoting to other departments men on whom he depended is one of his most broad-minded and lovable traits. Fairness and honesty are carried almost to obsessions. An honesty that refuses to countenance deception, either direct or through half-truths, and fairness that does not desire a business deal in which the other party cannot also gain, renew our faith in the uprightness of successful business men."

by N. Ransohoff
Cincinnati, Ohio

Metal cleaning by tumbling and burnishing

METAL CLEANING is an operation the object of which is to remove grease or other foreign matter without disturbing the basic surface or contour of the work. In contrast to this, the objects to be attained by tumbling and burnishing all involve some change in the surface of the work itself. Cleaning operations therefore primarily involve chemical reaction and solution; machinery for the work can be almost unlimited in design but nearly always falls into two distinct types, *(a)* conveyor type used for large work or very delicate work and *(b)* the drum type. This discussion will confine itself to the second type.

While the drum type of cleaning involves less labor, the size and nature of work that can be suitably processed depends largely on the machine; any work that is sufficiently rugged to be handled loose in tote boxes can be satisfactorily cleaned in it. It is not confined to small articles for parts up to 12 in. diameter are being cleaned in the larger drums.

In true cleaning operations the work is not actually *tumbled;* it receives rather a very gentle agitation as it is impelled forward from the charging to the discharge end by the slow rotation of the drum. The machine must be built so that the work slides or rolls gently from one section of the machine to the next. With a unit designed in this way, even finished roller bearings are being satisfactorily cleaned of oily film without damage.

An efficient design will include a soaking wash in the first section of the machine, followed by a spray wash in the second section, this in turn to be followed by a drain. The soaking wash softens the dirt and gets into holes which the spray might not reach. The spray then drives off any of the softened dirt yet adhering to the pieces. The work should pick up sufficient heat while soaking in the hot cleaning compound to aid in the drying. On such heavy work as bolts and machined parts where the mass of the work is great compared to the surface, a drier is rarely necessary if the parts have been immersed in hot cleaning compound and well washed.

Solution tanks are usually heated by either steam coils or submerged gas flues, unless a very low electric rate is available. The tank should be below the drum; cleaning compound is circulated by a pump drawing from the bottom, the accumulated scum floats on top the heating tank and the parts are washed in the cleanest part of the compound. The tank should be equipped with an overflow skimming dam so that when new solution is added to the circulating system the scum floats off to the sewer. For most work a chip pan and removable basket are also necessary to screen out the chips washed off the work by the compound so as to avoid fouling the pump.

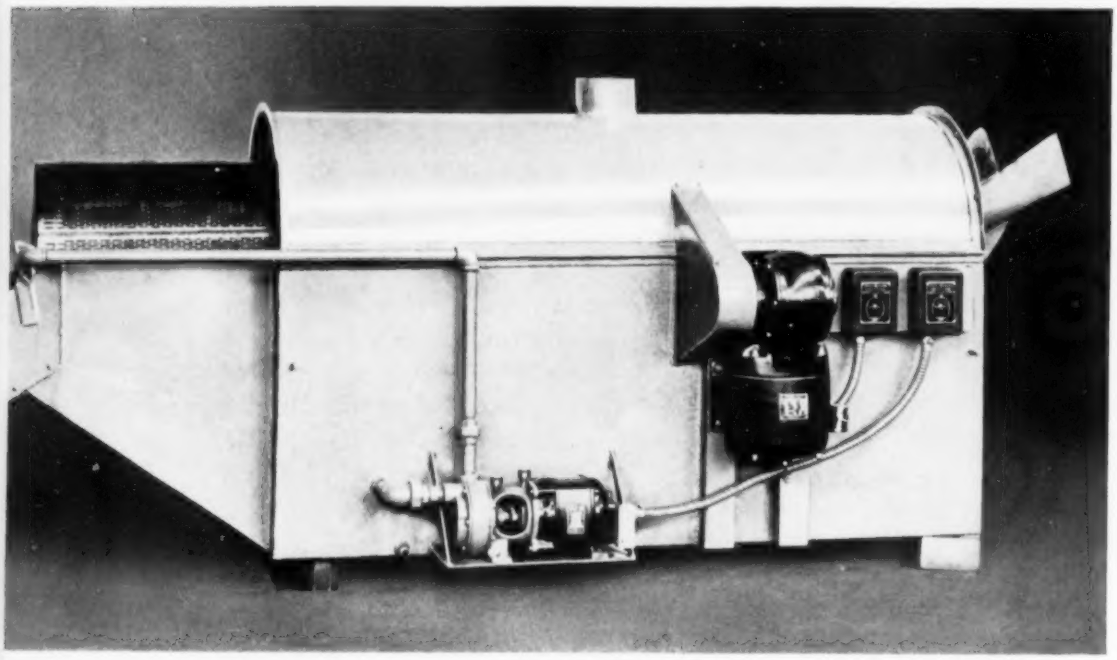
Rugged continuous machinery may easily be built for several operations in the same unit; for example, a wash, cold rinse, hot rinse and dry. Drying is best done by a hot air blast blown onto the work through a slot in a pipe extending through the center of the drying screen. Air may be heated by steam coils or by a gas air heater;

in any case, the construction should be such that some air is continually drawn in, fresh and dry.

Where quantities of work are handled, the machine should have a power loader to avoid shoveling the work into the machine or the lifting of tote pans for dumping — a very handy device if slight abrasion of finished parts need not be avoided. These loaders are usually electrically operated by push button and limit switch control; they are commonly patterned after the common loaders on concrete mixers.

Where there is a great amount of dirt to be removed from the work and this dirt accumulates in the tote pans, a small conveyor may be built alongside the drum on which they can be placed upside down to be washed by auxiliary spray as they pass along a covered passage before reaching the discharge end to receive the clean work. All this, of course, can be done automatically. For large production, machines have been built to pick up total loads of 2200 lb., consisting of 2000 lb. of work and a 200-lb. tote pan or shop box. The loader automatically dumps the work and delivers the shop box upside down on a conveyor above the drum. The box is cleaned in passing along this conveyor and is delivered right side up in position to receive the clean work coming from the drum.

The continuous machine has the disadvantage that work comes from the drum at a definite rate whether it is clean or not. Therefore, for cleaning preparatory to plating or other precise cleaning jobs where chemical cleanliness is required, the batch process is likely to be more satisfactory. While many designs are possible, in the drum type of cleaner the tank and circulation systems are usually similar to that noted above. The drum, however, is so constructed that when it rolls in one direction the work remains in the drum, constantly agitated in hot cleaning compound. Work may therefore be kept in the drum as long as is necessary; reversal of the driving motor automatically discharges the batch. A slight change in the piping connections will enable the work to be rinsed; drains will be equipped with proper valves so that rinse water is deflected to the sewer. Speed of the drum on a batch process machine should be set to accomplish the desired results. Some work requires tumbling after it comes from the punch press to brighten it and remove press burrs; a speed of about 16 to 18 revolutions is then proper. For cleaning without tumbling, the drum should rotate four to six r.p.m. A variable speed transmission will enable a properly designed unit to be used for both types of work.



Continuous Washer, Completely Self Contained, Hooded to Exhaust Vapors. First section of drum is solid, with device for holding level of cleaning compound yet delivering work to second, perforated section for washing. In last section at left work is drained. Welded construction of deflectors prevents lodgment of small work

If production warrants, batch machines may be set up in series, one discharging into the next. Work may then be taken direct from the punch press and delivered, washed, rinsed, plated, sawdust dried and tumbled without being handled at any intermediate step. A typical layout would include: Wash or soap roll, rinse or water roll, nickel plate, rinse, soap dip, sawdust dry and tumble.

When batches are smaller, two individual units of this type may be used. The unit for washing and rinsing before plating may well be arranged to discharge the work directly into the plating barrel. The unit for rinsing and drying after plating is equipped with a hopper to receive the work from the plating barrel (the barrel being of the type which may be hoisted from the tank of electrolyte with a small monorail hoist).

Tumbling and Burnishing

So far we have considered cleaning as differentiated from tumbling. This latter operation is also done in a drum type machine, but here the similarity of the two operations ends. The objects to be attained by tumbling all involve some change in the surface of the work itself. Four general objectives may be achieved, as described below.

First is the removal of scale from forgings or hardened machined parts, or scale and sand from castings. Very small forgings or castings without re-entrant surfaces may be tumbled on themselves, since they form their own tumbling material. Among forgings of this type are forged nut blanks and hot pressed bolts; certain small malleable hardware castings are also frequently cleaned in this way.

More complicated castings and forgings require stars to reach all the parts of the surface and to do a thorough cleaning job. Stars usually used range upwards from 3/8 in. in size. When the work to go through is uniform in size and design, the stars must be carefully chosen so they will not jam in any holes — some of the stars must be small enough to go freely in and out of the holes to clean the inside surface; others must be large enough so they will not enter or stick in the holes.

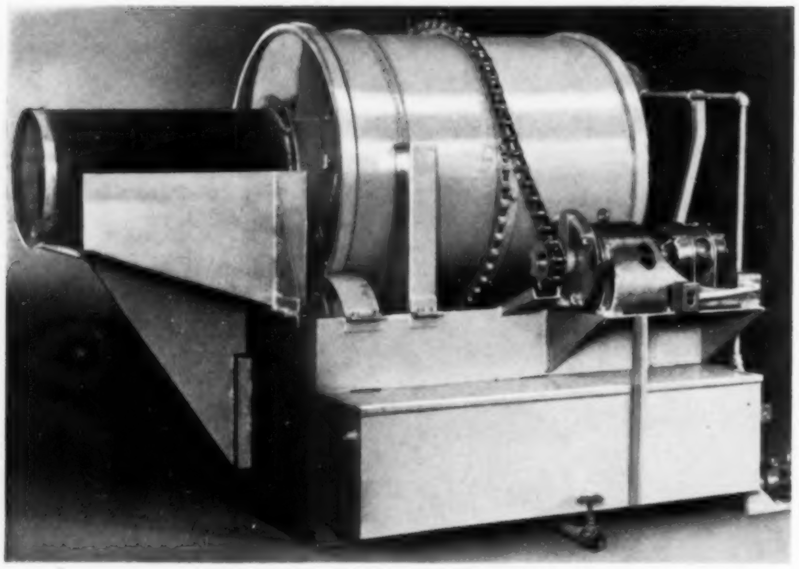
It Is Found That Roll Tumbling of Stainless Steel Fasteners in Soapy Water Improves the Luster on Finished Parts. Courtesy Lamson and Sessions Co.

Stars serve two purposes. First, they remove the scale from depressed surfaces and holes. Second, they form a cushion and prevent parts from dropping on each other and nicking the corners. For this reason it is necessary to use an ample supply of stars to get a clean, smooth surface without dents, pock marks or nicked corners. Depending on the nature and weight of the parts to be cleaned, the weight of the stars should be from 75% to 150% of the weight of the work.

Comparatively fragile parts can be successfully tumbled with proper tumbling material. The writer has seen rough turned and hardened piston pins, and hardened and threaded shackle bolts descaled without injury to either the corners or the threads. In this case the work was tumbled with hardened punchings approximately 1/4 in. diameter by 1/4 in. thick, sufficient in quantity to float the work thoroughly.

Castings and forgings may be descaled dry or in a weak solution of basic cleaning compound either with or without sand. If the tumbling is done wet, the work should be discharged from the barrel into a tank of hot basic cleaning compound. A simple way to do this is to set a basket in the tank at the discharge end of the barrel; when the basket is full it can be raised and lowered by an electric hoist to slush off the loose dirt and then hoisted from the tank.

This wet method of tumbling has several advantages. In the first place, it eliminates the dust nuisance which does away with exhaust systems and the problem of protecting bearings from dust. In the second place, the hot cleaning compound leaves a light deposit on the work



Batch Barrel for Water Rolling or Soap Rolling. Reversal of rotation discharges drum into draining screen, ready for next operation

when it dries which helps considerably in rust proofing the parts until they are used. Equipment of this nature for tumbling small forgings in weak acid, screening out the stars, neutralizing the carryout and discharging dry work, was described in METAL PROGRESS for March, 1934.

A second objective of tumbling is to remove burrs or sharp edges from stampings, nut blanks, trimmed bolts, and such parts. This may be done either wet or dry with sawdust.

Frequently such work must also be delivered clean enough for plating or for easy handling in subsequent assembly. In this case, tumbling and cleaning can be simultaneous if the barrel is equipped with a heating tank and circulating pump so that the hot cleaning compound cascades over the work while tumbling. The drum should have perforated patches for the escape of the cleaning compound carrying away chips and other foreign matter. In a specific case, the backs of safety razor blades are first rolled in a circulating soap solution, automatically discharged into a second barrel, which gives them a water roll, and from this water roll they are discharged directly into a nickel plating barrel.

When but little grease is to be removed, sawdust tumbling is adequate. This is the case with cold pressed machine bolts, machine screws and certain classes of stampings. Sawdust not only removes light grease, but also gives the work a certain degree of polish. On some stampings where scale is to be removed, as well as sharp edges and a light press grease, the work is tumbled with a mixture of sawdust and small stars. If a large amount of oil or grease is to be taken off, sawdust is not economical, since it rapidly becomes contaminated, and the cost of the sawdust as well as the labor in renewing it is considerable.

A third purpose of tumbling is to smooth the surface of stampings, forgings, or castings. In shop parlance this is known as "cutting down." It usually precedes burnishing and has been practiced in stove and hardware foundries for years. The work is usually tumbled in small barrels on itself with either sand and water or oil and emery as an abrasive. It is sometimes necessary to add additional tumbling material such as slugs or small stars. "Cutting down" usually takes from 10 to 100 hr., and is limited to comparatively small pieces. A quicker cutting down process is also used to prepare hardened machined parts or forgings for burnishing. In this case, no sharp edges or irregularities in the surface are removed, but simply the forging or hardening scale, which would otherwise prevent satisfactory results during the burnishing process.

Lastly is the process of burnishing, which further smooths the surface of stampings, die castings and small parts *(Cont. on page 76)*

Burnishing Barrel Adaptable for Various Sizes of Work. When barrel is tilted slightly above horizontal and rotated left hand the balls are trapped in chamber at rear. Small work is loaded through door at side; large work (in racks) through removable cover. Hollow shaft enables the work and balls to be washed and rinsed during the process

Correspondence and foreign letters

French Tool Steels

PARIS, *France* — There is no official or standard classification of tool steels now existing in France; however, every firm making such products will market two principal kinds:

I. Carbon tool steels. Each tool steel maker will have from two to ten series of carbon steels, each series subdivided into grades according to carbon content, which may range from 0.6 to 1.5%. One series is distinguished from another by its degree of purity, the nature of the raw materials used, and more particularly by such characteristics as the penetration of hardening, the resistance to coarsening on superheating, and the appearance of the fracture.

II. High speed steels. These contain from 12 to 24% of tungsten, 0.6 to 0.8% carbon, 4 to 5% chromium, and more or less important additions of vanadium, molybdenum and cobalt. Many attempts have been made to classify the French steels according to the tungsten, vanadium, and cobalt content. The present tendency is to simplify matters by classifying them only according to tungsten content, thus

Series I, 10 to 12.5% tungsten
Series II, 12.6 to 14.5% tungsten
Series III, 14.6 to 16.5% tungsten
Series IV, more than 16.6% tungsten

The types most commonly used are of Series IV, containing 18% tungsten, 4% chromium and 1% vanadium, an analysis which is approximately equivalent to the ones quoted by J. V. Emmons and F. Giolitti in METAL PROGRESS (December, 1933, and June, 1934, respectively). Second choice for general cutting tools would be a 14% tungsten, 4% chromium analysis of Series II. A steel containing 22% tungsten, 4% chromium is widely used for milling cutters.

However, in addition to these two principal classes of tool steels, a number of others exist.

For instance, special elements are added to the carbon tool steels noted above, up to 6% tungsten, 2% chromium, 2% manganese, 0.5% molybdenum and 0.25% vanadium either singly or in combination. These are adapted for cutting hard metals at slow speed, or for intricate or precise tools hardened in oil with small volume change. The last-mentioned requirement is also met with another type of steel, containing 3 to 12% chromium with high carbon (1.5 to 2.5%); of late cobalt, tungsten and molybdenum have been added to these by some makers. These last-mentioned steels have a very low critical hardening speed, and thus are air hardening, and quite stable in dimension. Their metallographic constitution is comparable to white cast iron.

If less brittleness is desired in tool steels, the user may purchase stronger steels with smaller carbon content (0.3 to 0.5%) and up to 3% tungsten and chromium. Similar low carbon steels with about 10% tungsten and about 3% chromium are favored for forming hot steel bars (hot working dies) and fast screw cutting or rolling dies. Where massive tools are to be made (as drop hammer or forging dies) self-hardening steels are of course used, to obtain a greater penetration of hardness and more uniform surface hardness. This is ordinarily done by adding from 1.5 to 5% nickel, and such die steels may contain one or all of the following: Up to 2% chromium, 0.5% molybdenum, 0.5% vanadium, and 2% tungsten.

ALBERT PORTEVIN

Light Weight Cylinders for Compressed Gas

TURIN, *Italy* — One application where aluminum alloys have given remarkable results is the manufacture of cylinders for transporting gas under high pressure. Steel, of course, is the material most commonly used for gas cylinders (for handling oxygen, nitrogen, helium, CO_2, NO, and other industrial gases), but the weight and value of such a container is so many times the weight and value of its contents that transportation and capital charges are sometimes a serious item. As the light alloys used for this purpose in different countries vary within wide limits, it may be interesting to quote a few data concerning Italian practice.

Special care has been given to this problem by the firm Stabilimenti di S. Eustacchio which is now our largest manufacturer of aluminum alloy cylinders for high pressure gases. Complete technical data concerning the product have been published by E. Franchi.

For this purpose are used principally the three well-known alloys "Avional," "Lautal" and "Anticorodal," whose compositions and tensile properties (after rolling and heat treatment) are shown in the following table:

Properties of Aluminum Alloys

	"Avional"	"Lautal"	"Anti-corodal"
Nominal Composition			
Copper	4.0%	4.0%	
Silicon	0.6	2.0	1.0%
Manganese	0.6		0.6
Magnesium	0.6		0.6
Iron	0.35	0.35	0.35
Mechanical Properties			
Ultimate strength (psi.)	54,000 to 64,000	54,000 to 60,000	35,000 to 40,000
Elastic limit (psi.)	35,000 to 40,000	28,000 to 38,000	28,000 to 34,000
Elongation (%)	16 to 20	18 to 25	18 to 22
Brinell hardness	95 to 105	90 to 110	70 to 75
Specific gravity	2.76	2.75	2.72

Anticorodal — notwithstanding its somewhat lower mechanical properties — is very useful on account of its excellent resistance to chemical attack by humid air and sea water. Special care has to be taken during forging and drawing through dies, because, as is well known, the intervals of temperature in which these operations can properly be performed are rather narrow. Heat treatment consists essentially of a careful preheating for homogeneity, followed by quenching and tempering.

An extremely long series of accurate tests had to be made before public authorities gave permission to put these cylinders on the market. The second table shows the extreme limits and the average values of the transverse mechanical properties of a number of cylinders made of anticorodal. The size of the test pieces was 0.80x0.20x4.33 in., and the high degree of uniformity of the material is evident.

Transverse Properties of 40 Cylinders ("Anticorodal") Test pieces 20x5x110mm. (0.79x0.20x4.33 in.)

	Minimum	Maximum	Average
Ultimate strength (psi.)	54,500	55,700	55,000
Yield point (psi.)	32,700	34,700	33,200
Elastic limit (psi.)	29,900	32,000	31,000
Elongation (%)	17.3	21.8	18.7
Reduction of area (%)	27.0	29.8	28.4
Brinell hardness	106.3	107.8	107.3

The results of hydraulic tests on finished gas cylinders accurately checked those calculated from the above figures. The behavior of the bottles under pressure is shown in the table, which refers to a cylinder made of lautal, of about 275 cu. in. capacity, designed for holding gas at ordinary pressure: 150 atmospheres (2200 psi.).

These data were obtained with standardized testing routine, as laid down by regulatory commissions, and show a large margin of safety — at any rate, a margin fully sufficient to meet the Italian standard specifications for steel cylinders.

Test on Completed Cylinder ("Lautal") (Capacity 20 cu.ft. at 150 atmosphers)

Pressure (atmospheres)	Stress in Metal (psi.)	Increase in Diameter (in.)		Increase in Volume (cu.in.)	
		Elastic	Plastic	Elastic	Plastic
50	4,500	0.001		0.049	
100	9,000	0.002		0.100	0.003
150	13,600	0.003		0.153	0.005
200	18,100	0.004		0.204	0.009
250	22,600	0.006		0.259	0.015
300	27,200	0.007	0.002	0.315	0.023
430	39,800		0.038	1.433	0.994
500	48,600		0.098	3.55	3.04
570	64,000		0.118	Burst	

It may be remarked that bursting occurs under a strain equal to the longitudinal strength, but far superior to the *transverse* tensile strength of the material (which is only about 52,000 psi.).

It is known that this is an effect of the thick top and bottom of the cylinder on the general resistance of a relatively short tube.

The yield points and the general properties of the above-mentioned alloys permit us to manufacture pressure cylinders which do not weigh half as much as steel ones meeting the same legal standard specifications.

Cylinders of the more or less standardized sizes, containing up to 200 cu. ft. of gas compressed to 150 atmospheres, are now being made in large quantities.

FEDERICO GIOLITTI.

Hydrogen as the Cause of Flakes in Steel

SCHWEINFURT, *Germany* — My letter to METAL PROGRESS published in July discussed various theories that had been advanced about the formation of flakes. As will now be shown, the modern offsprings of metallurgy, physical chemistry and X-ray analysis have brought new and positive information on the subject; namely, that pressure caused by hydrogen is the essential factor in the formation of flakes, and that other phenomena, such as segregation, inclusions and mechanical stress, are often the critical factors determining whether these inner forces are sufficient for the formation of flakes or not.

It is not now claimed that when hydrogen is present in large amounts flakes must always occur. However, there is abundant evidence to show that hydrogen *is* present in steel; the quantities derived from experiments differ for several undefined reasons, some doubtless related to the past history of the metal and the experimental procedure. It can also be assumed that hydrogen segregates like other elements, for example sulphur and phosphorus, and that cracks will develop in places weakened by such segregation if sufficient hydrogen is free to develop the necessary internal bursting pressure. According to this theory, then, when internal discontinuities and stresses are supplemented by hydrogen pressure, this will be the immediate cause of flaking in the solid steel, occurring at low temperature.

While metallographic methods can be used to determine segregations of phosphorus and sulphur, they are not applicable to the identification of gaseous enrichment at certain spots. Here may be mentioned the interesting work of Esser, Eilender and Bungeroth reported in *Archiv Eisenhüttenwesen*, 1934-35, page 419. They investigated a flaky sample of chromium-nickel steel. Gas is evolved from flaky spots in a broken piece when rays impinge on it. Likewise a stratum rich in chromium, nickel and manganese was found. On the basis of these experiments they arrived at the hypothesis that the basic structure of the steel is embrittled by precipitation of hydrides and that hydrogen is formed by subsequent dissociation of the hydrides. This produces such a high internal pressure that cracks or flakes are caused in the brittle structure of the material.

Definite evidence is available about the evolution pressure of hydrogen at various temperatures from steel castings containing various amounts of hydrogen. This work was done by L. Luckemeyer-Hasse and H. Schenck. From their curves (reproduced in *Technische Mitteilungen Krupp* for April) it can be seen that this evolution pressure from a steel containing 0.001% hydrogen by weight is about 3000 psi. at 1000° F., and it rises rapidly to about 130,000 psi. at 600° F. Similar data are contained on these curves for lower hydrogen concentrations, and indicate that the tensile strength of pearlitic steel (roughly 60,000 to 85,000 psi.) is exceeded by the evolution pressures of hydrogen from steel containing as little as 0.0003% of it at temperatures of 400° F. and below.

This theoretical conception was correlated with practical observations in the plant. Extensive new investigations by Messrs. Houdremont and Korschan at the Krupp plant in Essen led to the conclusion that hydrogen is probably responsible for cracks in steel. These interesting and significant experiments are reported in the publication mentioned immediately above; note should also be made of the discussion in *Stahl und Eisen*, 1935, p. 328, which gives the viewpoints of other German metallurgists.

It is also probable that methane can be formed at fairly low temperature by a reaction between dissolved carbon and dissolved hydrogen. Schenck and his collaborators, from considerations in physical chemistry and the above-mentioned experiments with hydrogen in steel, have computed that the pressure developed by such methane at 1000° F. is on the order of 750,000 psi., many times greater than the strength of any commercial steel!

In conclusion, it can be said that in accordance with the above-described new experiments, hydrogen may be regarded as primarily responsible for flakes in steel, when the latter are cooled too quickly through a relatively low temperature range. Segregations, thought by many to be the

prime culprit, cannot be cleared of all blame, however, for segregations, inclusions, and internal stresses of all sorts produce metal with impaired tensile strength and these regions are more likely to show flakes from hydrogen pressure than completely homogeneous and unstressed metal. HANS DIERGARTEN

Endurance of Nitrided Steel

Moscow, *U.S.S.R.* — An experimental program has been completed by the writer at the Scientific Research Institute for Aircraft Materials, under the direction of Prof. G. W. Akimow, in which we studied the endurance of two steels in the normalized, heat treated and nitrided conditions. One was a plain chromium steel corresponding approximately to S.A.E. 5150, except that silicon was high (0.38%) and the other a complex alloy steel containing nearly 1% of aluminum. Its composition is

Carbon	0.34%
Silicon	0.25%
Manganese	0.45%
Chromium	1.60%
Nickel	0.47%
Aluminum	0.83%
Molybdenum	0.63%

The steels were subjected to standard tensile and impact tests, and fatigue tests under repeated bending and torsion. The chromium steel was studied in the normalized condition and after drawing, to various temperatures, the steel quenched in oil from 1560° F.

The complex nitriding steel was tested as received, and then after nitriding for various periods. All specimens were quenched from 1750° F. in oil and drawn at 1200° F. before nitriding. Results are contained in the table.

On the basis of the data obtained, the following conclusions were drawn:

1. Endurance limit of both steels to reversed bending and reversed torsional stresses changes with the drawing temperature in the same direction as tensile strength, yield point and proportional limit.

2. The relation between endurance limit in bending (E_b) expressed in pounds per square inch, and the proportional limit in tension (P) is expressed for the chromium steel by the empirical formula $E_b = 24{,}000 + 0.41P$

3. Endurance limit under torsional stresses (E_t) when determined by the long-time method, closely agreed with the value computed by the Gough empirical formula $E_t = 0.56E_b$

4. Accelerated methods of testing under bending and torsional stresses showed higher values than those given by long-time testing. The step method suggested by Mailander gave good results, especially for nitrided specimens.

5. Given constant mechanical properties in the core, the endurance limits of nitrided specimens in repeated torsion and bending both increase with increasing depth of case.

6. The ratio between the endurance of the nitrided specimens to repeated bending stresses and the tensile strength of the nitrided core is higher when the nitriding is done in two stages, 950° F. and 1200° F., than when it is done as usual at 950° F.

7. Nitriding raises the endurance limit more when testing is done by repeated bending than by repeated torsion.

8. If nitriding is forced to great depths the endurance limit of nitrided specimens can equal the yield point of the steel. Nitriding, therefore, may be considered a method of increasing the endurance of nitrided articles, even when a high surface hardness is not required (in which case, of course, aluminum-free steels may be used).

E. J. KONTOROVICH

Endurance Limit of Nitrided Steel

Nitriding: Temp. °F.	Nitriding: Hours	Depth of Case In.	Endurance Limit in Bending: Mailander's Step Method	Endurance Limit in Bending: Long-Time Method, (E_b)	Endurance Limit in Torsion: Accelerated Method	Endurance Limit in Torsion: Long-Time Method, (E_t)	Tensile Strength of Core (S)	Ratio $E_b \div S$	Ratio $E_t \div S$
As received		None	—	70,000	48,000	41,000	143,000	0.49	0.29
950	30	0.012	92,000	82,000	54,000	46,000	143,000	0.55	0.32
950	50	0.017	98,000	85,000	56,000	48,000	143,000	0.60	0.34
1025	30		—	84,000	57,000	46,000	—	—	—
1200	30	0.033	—	90,000	41,000	44,000	118,000	0.70	0.37
950 +1200	10 10	0.021	93,000	85,000	48,000	46,000	128,000	0.67	0.36
1200 +950	10 10	0.020	—	78,000	47,000	43,000	122,000	0.65	0.35

Molybdenum-Tungsten High Speed Steel

Springfield, *Mass.* — After reading the interesting article "New High Speed Steel" by Frank Garratt in the June issue, the writer arrived at some different conclusions from the data presented in the diagram on page 42 of that article (reproduced on this page). The curves show that the molybdenum-tungsten steel has greater toughness at all drawing temperatures. However, it cannot be denied that quenching 18-4-1 standard high speed at 2375° F., as called for in the caption of the diagram, gives distinctly less favorable impact properties than temperatures in the range of 2325 to 2350° F., the generally recommended temperature. The data, then, appear to have been derived from samples of the standard tungsten type of high speed treated considerably higher than is usually found to accord with its most favorable mechanical properties.

Another phase of this perhaps can best be seen from the drop in plasticity of the molybdenum type when it is quenched from a temperature only 25 to 35° F. higher than the 2190° F. used for these data.

Notwithstanding this apparent dissimilarity in treatment, the difference in toughness as shown on the diagram at the respective peaks of secondary hardness is within reasonable experimental error. This is much more significant than the high toughness after low draws, since perhaps over 95% of all high speed steel is tempered in this high range.

Another point of interest in the diagram is the definite indication that the so-called "red hardness" of the molybdenum type is at a maximum some 70° F. lower than that of the tungsten type. While the curve representing room temperature hardness after various drawing heats cannot be used as an absolute index of red hardness, it is nevertheless clear from this diagram that if both materials were operated at 1100° F., the molybdenum type would be tempered (as a result of coalescence) to a lower room temperature hardness than the tungsten type.

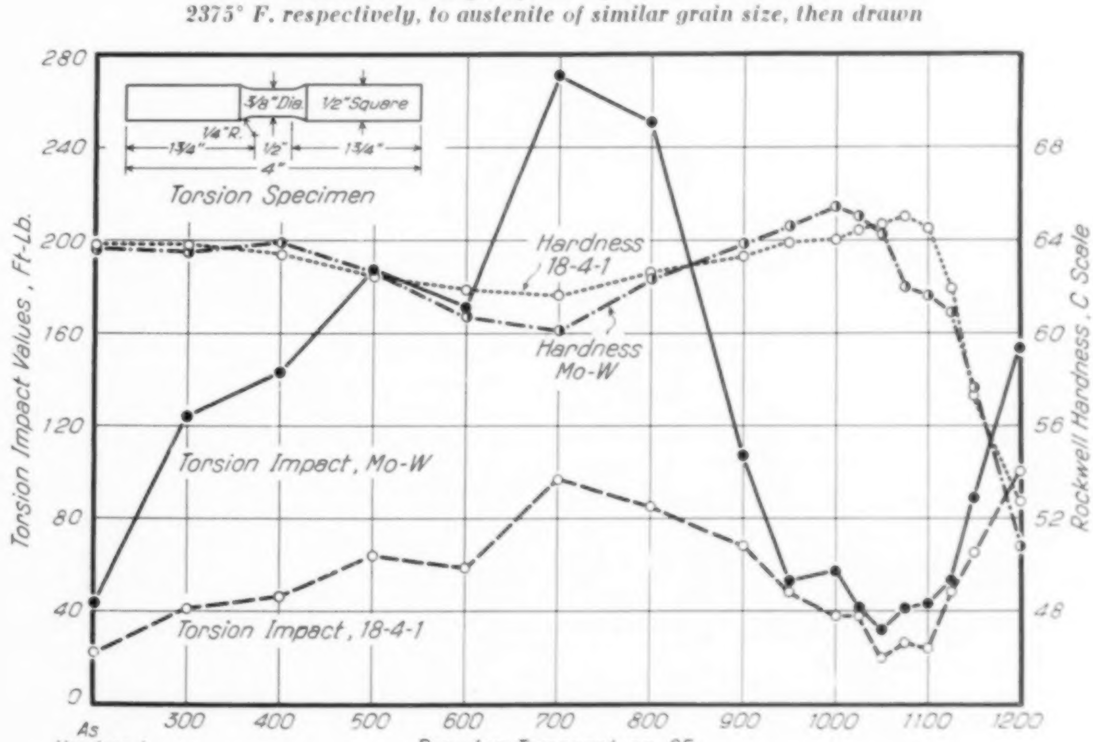
Robert S. Rose
Metallurgical Department
Vanadium-Alloys Steel Co.

Mr. Garratt Replies

Bridgeville, *Pa.* — While Mr. Rose's criticisms are welcome, I do not agree with his conclusions! In the first place, it is useless to criticize quenching temperatures unless the important factors of holding time at hardening temperature and type of hardening atmosphere are fully considered.

I believe that it will be conceded by most

New High Speed Is Somewhat Harder and Considerably Tougher Than Standard 18-4-1 High Speed. Quenched from 2190° F. and 2375° F. respectively, to austenite of similar grain size, then drawn



workers familiar with 18-4-1 high speed steel that a hardening temperature of 2375° F. will produce a tool having better *cutting* properties than one hardened at 2337° F., and when the lower temperature is recommended it is because one is willing to sacrifice cutting qualities for better toughness.

The torsion-impact tests intended to show that when both types of steel were heat treated to give maximum *cutting* properties, the 18-4-1 material was not as tough. It might be admitted that the use of lower hardening temperatures would impart better toughness to the 18-4-1 specimens, but such lower temperatures would result in loss of cutting properties. (It is equally true that the use of lower hardening temperatures for the molybdenum-tungsten specimens would give still greater toughness than the values shown, the relative differences being about the same as those shown in the chart.)

I question the authority for Mr. Rose's statement that quenching temperatures 25 to 35° higher than 2190° F. quoted in the caption would cause a large drop in plasticity of the molybdenum steel, since no such data are given in the paper he is discussing.

As regards the torsion impact values at the points of maximum hardness showing differences within the limits of experimental error, it should be emphasized that the values shown are averages of three well-agreeing results. It is also worth while emphasizing that molybdenum-tungsten steel, at its point of maximum hardness, has average torsion impact values of 57 ft-lb., while the 18-4-1 material at its point of maximum hardness has only 26 ft-lb.

I do not follow Mr. Rose's reasoning in his last paragraph. The tempering curves show that maximum hardness of the molybdenum-tungsten type, as measured at room temperature, is developed at slightly lower temperatures than in the case of the tungsten type, but it does not follow that this fact is of any consequence in considering tool life, or that it gives any indication of the qualities of the two steels under operating conditions. It would seem to me that the *stability* of the microstructural constituents formed at the temperature required to produce secondary hardness is a matter of prime importance, as well as the correlated properties of hardness at operating temperature and resistance to wear. The fallacy of any reasoning associating secondary hardening temperatures with cutting properties is further disclosed when it is appreciated that the so-called super high speed steels have about the same secondary hardening temperatures as 18-4-1 material.

In this connection one cannot ignore the hardness of the heat treated steels *at elevated temperatures*. Some pertinent figures were submitted by J. V. Emmons in his discussion of Harder and Grove's paper in *Transactions*, American Institute of Mining & Metallurgical Engineers, 1933. Emmons showed that molybdenum-tungsten steel, similar in composition to that tested by the present writer, had a Brinell hardness of 380 at 1202° F., while 18-4-1 material tested under identical conditions showed a Brinell hardness of 329.

At any rate, speculation as to probable cutting ability takes second place to performance records in service, and these undoubtedly are favorable to the new tungsten-molybdenum high speed steel.

Frank Garratt

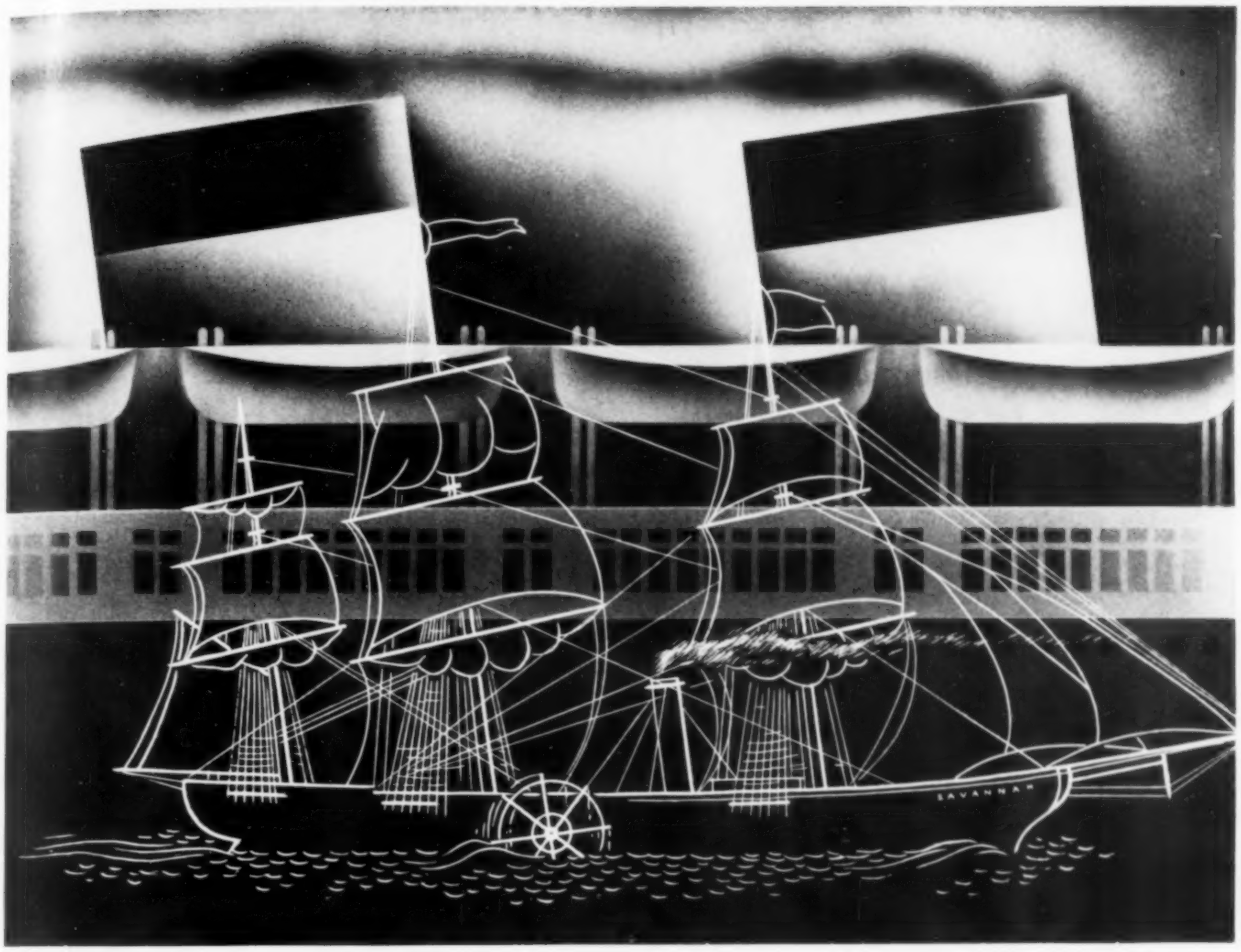
Improved Magnetic Alloys

Sheffield, *England* — The article published in Metal Progress in July by Dr. Merica on "Some Alloys Having Great Thermal and Magnetic Stability" quotes in error from Koester's work in *Stahl und Eisen* for August 17, 1933. The hysteresis loops shown on your page 42 refer to iron-molybdenum-cobalt instead of iron-tungsten-cobalt as noted in your caption. The first-mentioned alloys give a maximum coercive force of 300 to 350 c.g.s. units, whereas the iron-tungsten-cobalt alloys give a maximum coercive force of 150 to 180 c.g.s. units. There is a further slight error in the diagram, for the term "magnetic reluctance" should read "coercive force."

Koester's article may have been somewhat misleading to the translator, as he mentions the diagram showing the hysteresis curves of iron-molybdenum-cobalt alloys, while his text refers to the iron-tungsten-cobalt alloys.

Iron-tungsten-cobalt form the cutting tool alloys and iron-molybdenum-cobalt the permanent magnet alloys. These latter cannot compete in price or performance with the nickel-aluminum type. The latest developments in this country — that is, the addition of cobalt and copper to the nickel-aluminum type — have resulted in a further improvement by obtaining a higher remanence (8000 to 9000 gauss) with a high coercive force (500 to 600 c.g.s. units).

J. C. Swan
Metallurgical and Research Dept.
English Steel Corporation



Book reviews

(Cont. from p. 48) transportation, storage, vaporization equipment and distribution of these gases (which constitute new problems even to many familiar with utilization of city gas) are comprehensively discussed.

Several chapters are devoted to the increasingly widespread use of propane and butane gases in the industrial and commercial fields. Applications for these fuels in industrial furnaces, internal combustion engines, central plants, and domestic appliances are given prominence, and equipment and design features which are necessary to permit their most effective utilization are also included.

In general, this handbook should serve as a valuable reference for those interested in any phase of the production, transportation, analysis, or utilization of propane and butane gases.

E. O. Mattocks

Cutting of Metals

A Bibliography on the Cutting of Metals; Part II; by Orlan W. Boston. 202 pages, $5\frac{1}{4}$x$8\frac{1}{4}$ in. Published by Edwards Bros., Ann Arbor, Mich. Price $2.50.

Part I of this bibliography was prepared by Professor Boston and printed by American Society of Mechanical Engineers in 1930. In the subsequent time an even greater number of publications have appeared, which are here listed, and each one briefly abstracted. Lacking funds for publication uniform with the first part, the present book has been printed by photo lithography from excellent type script. A reduction of 70% of single spaced copy still makes a very legible page.

From a cost standpoint, this saves type setting, proof reading, and page lock-up. Against this is charged the slight extra cost of preparing letter-perfect copy and the photographic reproduction. The saving is such that the publishers believe it will enable them to publish scholarly and technical books in small editions without a subsidy. (One disadvantage is that the text is likely to suffer from the lack of that attention which skilled copy readers and proof readers give to a page of type.)

Professor Boston's present book is guaranteed by his eminence in the field of machine shop practice. Its scope might be judged too wide, rather than too narrow. The index should be very useful. It is cleverly arranged on a checkerboard; the column titles are the various classes of machine operations from planing to sawing, and the rows are various aspects of the general subject, like tool design, performance, or finish.

Enamels

Preparation, Application and Properties of Vitreous Enamels, by Andrew I. Andrews. 410 pages, 6x9 in., 124 figures, 62 tables of data. Twin City Printing Co., Champaign, Ill. Price $5.50.

This book by the professor of ceramic engineering at the University of Illinois is a manual of practice which will be very useful to anyone who is in charge of enameling operations, or engaged in the production or finishing of metal prior to vitreous enameling. Professor Andrews has had long contact with the industry, and his book abounds with "practical" suggestions — how to do the common operations in a way that will not lead to later trouble — as well as discussions about their fundamental nature.

More than half of the book is devoted to the influence of the metal base on the enameled surface and bond and its proper preparation, together with the spraying, dusting, or application otherwise of the slips, frit and colors, the construction and operation of the furnaces, and the testing and inspection of the finished ware. This is as it should be, for the discussion of the nature and manufacture of the enamels (raw material), while important, refers to matters which are largely taken care of for the metal worker and finisher by well-equipped manufacturing firms.

Heating Operations and Equipment

Industrial Furnaces, by W. Trinks. Vol. I, Third Edition. 456 pages, 6x9 in., 359 figures. John Wiley & Sons, New York. Price $6.00.

Professor Trinks' two-volume work on industrial furnaces was first published in 1923. Volume I contains principles and numerical data concerning heating capacity, fuel economy, durability of materials, and movement of gases. Volume II shows how these fundamental principles have been adapted to modern furnaces. The first part has sold readily, *(Cont. on page 70)*

Book reviews

(*Cont. from page 68*) and this new edition, expanded about one-third, has been rewritten in large part and entirely reset. The second volume, in contrast, seems quite antique, describing furnaces as they existed a dozen years ago.

Little more need be said about the new edition of Volume I than that the book is a mine of information about all matters connected with heat generation and transfer. It is quite up-to-date — for instance, the consideration given to heat resisting alloys and insulating refractories, while brief, appears adequate. It should be remarked that no space is given to "controlled atmospheres" — that is, the chemical interaction between hot gaseous mixtures and the work being heated. Furthermore, that furnaces for melting are not discussed, and consequently the chemical interactions between refractories, hot gases, and molten substances are not discussed, the book confining itself to heat treatment operations.

German Research

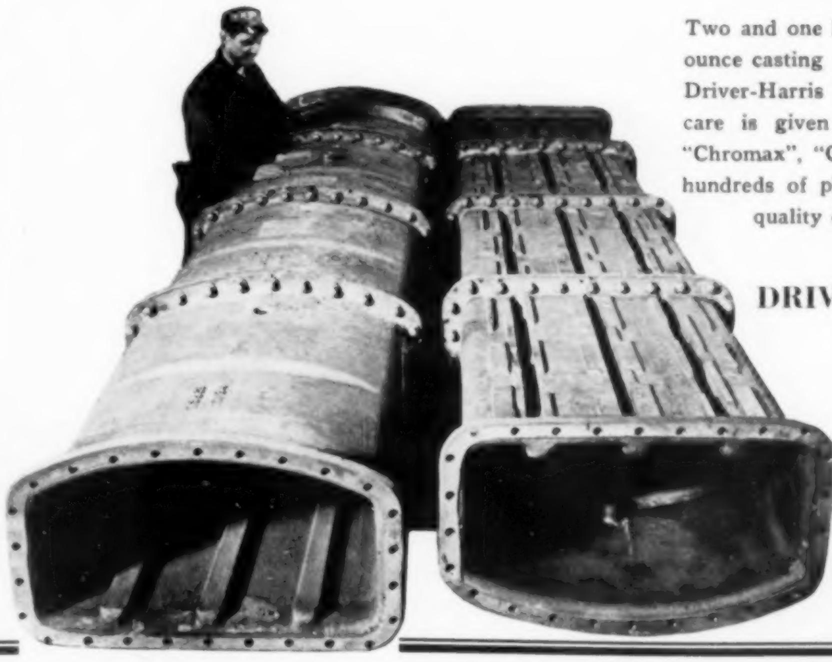
Publications of the Kaiser Wilhelm Institute, 1934. 239 pages, 430 illustrations, 80 tables. Published by Verlag Stahleisen, Düsseldorf, Germany. Price 27 RM.

The sixteenth volume consisting of 21 bulletins on iron and steel research carried on by the Kaiser Wilhelm Institute in Düsseldorf is now complete. As usual, it covers a wide variety of subjects ranging from theoretical chemistry, through metallurgy, strength of iron and steel, plastic flow, to purely mechanical properties of iron and steel. Each of the bulletins deserves a review of at least 250 words. Those who can read German, will profit by the study of these publications because they are excellent examples of German thoroughness and progressiveness. Many of them will doubtless be translated not only by our large steel concerns, but also by scientific institutions.

Of the many interesting subjects the following may be mentioned: Measurement of elastic stresses by X-ray; Hot drawing of seamless tubes; Metallurgy and production of induction furnace steel; Effect of carbon content on patenting and drawing of steel wire; Embrittlement of steel by hydrogen and brazing.

W. Trinks

2½ Ton Muffle
of CHROMAX*



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DRIVER-HARRIS COMPANY
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Spoilage Insurance

C. I. Hayes, Inc. has compiled a record of reports from over 300 users of their "Certain Curtain" controlled atmosphere furnaces showing how these furnaces have cut down spoilage in the heat treatment of tools and parts. Bulletin Sx-15.

Structural Welding

Reprints of an interesting article in *Journal* of the American Welding Society by A. F. Davis, covering welding of penstocks, a bubble tower, siphons, pipe lines, and an ocean pier, have been prepared by Lincoln Electric Co. Bulletin Sx-10.

Microscope Accessories

A 62-page catalog with index and price list describes and illustrates all sorts of microscope accessories, including a wide variety of objectives and eye pieces, made by Bausch & Lomb Co. Bulletin Sx-35.

Potentiometers

The construction and outstanding features of Brown potentiometer pyrometers are briefly described in an illustrated folder by Brown Instrument Co. Convincing testimonial letters from users are reproduced. Bulletin Sx-3.

Multi-Color Records

A handsome booklet describing Foxboro's multi-color potentiometer recorder for 2, 3, 4, or 6 temperatures reproduces charts in actual color. Specifications for one model are given. Bulletin Myx-21.

Centrifugal Compressors

B. F. Sturtevant Co. has a line of centrifugal compressors designed particularly for industrial furnace applications. These are illustrated and described in Bulletin Myx-58.

Silico-Manganese Steel

Silico-Manganese steel for heavy duty springs is the subject of Bethlehem Steel Co.'s new folder giving its properties and recommendations for heat treatment. Bulletin Jyx-76.

Radium Radiography

Advantages of portability, ease of application and manipulation in examination of castings, forgings, molds, weldings, and assemblies are attributed to radium for industrial radiography. Details are given in a booklet issued by Radon Co. Bulletin Jx-56.

Cyanides and Salts

R & H Chemicals Department of E. I. du Pont de Nemours Co. has a new 28-page manual on the procedure for case hardening, reheating, nitriding, and mottling of steels with cyanides, and on coloring, tempering, and drawing with salts. Nv-29.

Electric Furnaces

A wealth of information on controlled atmosphere electric furnaces is contained in General Electric Co.'s booklet by that name. Detailed data are given on electric brazing in particular. Bulletin Jx-60.

Steel Specifications

A handy, up-to-date specification sheet for carbon and alloy steels is offered by Timken Steel & Tube Co. On one page are printed analyses of all important types of Timken steels. Bulletin Jy-71.

Steel Shafting

Bliss & Laughlin has an attractive folder on their steel shafting, turned, drawn, ground, and polished to precision standards. Sizes and tolerances and uses are given. Bulletin Ax-42.

Pyrometer Accuracy

A thought-provoking folder of Hoskins Mfg. Company explains how the use of Chromel-Alumel for pyrometer lead-wires makes it possible to take full advantage of modern pyrometric instruments. Bulletin Ob-24.

Carburizing Retorts

Low cost, flexibility, uniformity, control, quality, and less labor with retort gas carburizing, says American Gas Furnace Co. Rotary, vertical and bell type retorts are described in Bulletin Jyx-11.

Metameter

Information on Bristol Co.'s Metameter, which makes it possible to control temperatures, pressures, levels, and other process conditions or operations at any distant place, is contained in Bulletin Ax-87.

Low-Cost Controller

Leeds & Northrup has a new low-cost Micromax controller for use where simple "on-off" control is adequate without indication or record, and where first cost must be low. Described in Bulletin Myx-46.

Misco Alloys

Compositions, properties, and application of Misco stainless, heat, and corrosion resisting castings are given in an illustrated folder offered by a pioneer producer, Michigan Steel Castings Co. Bulletin Mx-84.

Rockwell Tester

The Rockwell Superficial Hardness Tester is applicable to far thinner sheet and strip than the regular Rockwell. Its use for nitrided and case hardened parts is also described by Wilson Mechanical Instrument Co. in Bulletin Myx-22.

Cast Vanadium Steel

Jerome Strauss and George L. Norris have written a technical booklet for Vanadium Corp. of America describing the properties developed by steel castings containing various percentages of vanadium. Bulletin S-27.

Controlled Steels

Carnegie Steel Co. has published a very interesting booklet which describes in some detail the process control used in the production of uniform steels. Bulletin Je-85.

Welding Metallurgy

J. H. Critchett, vice-president of Union Carbide & Carbon Co., has prepared an exceptionally informative discussion of the physical and chemical principles involved in the oxy-acetylene welding of steel. Bulletin Ayx-63.

Conveyor Furnaces

Continuous chain belt conveyor furnaces *handle* miscellaneous parts without pans or trays — they are efficient, uniform, and flexible in operation. Improved furnaces of this type are described by Electric Furnace Co. Bulletin Ayx-30.

Alcoa Aluminum

The second edition of Aluminum Co. of America's 92-page book on "Alcoa Aluminum and Its Alloys" is packed full of valuable technical and practical data on all phases of the subject. Bulletin Ayx-54.

Maintenance by Welding

Industrial maintenance by Thermit welding is illustrated by actual applications to repair of street and railroad tracks, large machine parts, marine castings, crankshafts, and similar articles. Economy and permanence are featured. Metal & Thermit Co. Bulletin Ayx-64.

Beryllium-Copper

Beryllium-Copper is a relatively new alloy produced by American Brass Co. which can be heat treated to tensiles as high as 181,000 lb. per sq.in. It is supplied in sheets, wire rods, tubes and forgings. An excellent booklet gives full information on fabrication and treating. Bulletin No-89.

Turbo Compressors

The new items in Spencer Turbine Co's bulletin are a new and smaller "Midget" turbo for individual mounting, a single-stage line which effects new economies, and the gas-tight turbos for acid and explosive gases. Bulletin Mx-70.

Tempering Furnace

Technical details and operating data on Lindberg Steel Treating Co.'s new Cyclone electric tempering furnace, which has shown a remarkable performance record in steel treating operations, are given in Bulletin Fx-66.

Carburizing Boxes

Driver-Harris Co. devotes a folder to Nichrome cast carburizing boxes. Physical properties at room temperature and under operating conditions are given, as are the advantages of Nichrome castings for such service. Bulletin Jr-19.

S.A.E. Steels

The advantages of cold drawing in raising tensile strength and yield point are given in Union Drawn Steel Co.'s folder. It is accompanied by a copy of the newly revised S.A.E. steel specifications. Bulletin Jyx-83.

Heat Treating Manual

A folder of Chicago Flexible Shaft Co. contains conveniently arranged information on heat treating equipment for schools, laboratories and shops, and also illustrates the several types of Stewart industrial furnaces. Bulletin Ar-49.

Big-End-Up

Gathmann Engineering Co. briefly explains the advantages of steel cast in big-end-up ingots, showing the freedom from pipe, excessive segregation and axial porosity. An 82% ingot-to-bloom yield of sound steel is usual. Bulletin Fe-13.

Heat Resisting Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in Bulletin D-17.

Neophot

"Neophot" is the name of a new metallograph of radically new design and universal adaptability. A pamphlet distributed by Carl Zeiss, Inc., gives its applications and features and is well illustrated with beautiful samples of micrographic work. Bulletin Jx-28.

Blast Cleaning

A rugged blast cleaning cabinet for rapidly cleaning small work is described in a recent folder of Pangborn Corp. Full information on the operation of this machine is presented; many drawings and pictures are included. Bulletin Je-68.

Ni-Cr Castings

Compositions, properties, and uses of the high nickel-chromium castings made by The Electro Alloys Co. for heat, corrosion and abrasion resistance are concisely stated in a handy illustrated booklet. Bulletin Fx-32.

Carburizing Steel

High strength and ductility, forgeability, and machinability, combined with superior case carburizing properties, permit the attainment of maximum production with minimum cost. Such properties are obtainable in Jones & Laughlin's Jalcase steel. Bulletin Mx-50.

Recuperators

Results obtained with Carborundum Company's recuperators using Carbofrax tubes are fuel savings, closer temperature control, faster heating, and improved furnace atmosphere. Complete engineering data regarding application to various types of furnaces are given in Bulletin Fx-57.

Stainless Slide Chart

Carpenter Steel Co.'s pocket-size slide chart gives at a glance the technical data on all stainless steels. Bulletin Jyx-12.

Oven Furnaces

Surface Combustion Corp.'s standard rated, gas fired, oven furnaces are designed and built for heavy duty and continuous service at temperatures up to 1800° F. Complete information is contained in Bulletin Ayx-51.

Alloy Castings

A new bulletin on corrosion and heat resisting alloy castings is offered by Michiana Products Corp., manufacturers of Fire Armor and Zorite and other heat and acid resisting castings. Bulletin Jyx-81.

Testing with Monotron

Shore Instrument & Mfg. Co. offers a new bulletin on Monotron hardness testing machines which function quickly and accurately under all conditions of practice. Bulletin Je-33.

Textile Equipment

Republic Steel Corp. made an extensive survey of the textile industry. The very interesting results are reported in a folder which shows in color the effect of stainless steel and other equipment materials on dye colors. Bulletin Jzx-8.

Kanthal Alloys

C. O. Jelliff Mfg. Co. offers a descriptive booklet on Kanthal alloys. Certain of these alloys may be used as resistance elements; others are for furnace parts or other heat resisting applications. Full details are given in Bulletin Je-78.

Pickling Equipment

The material contained in a booklet on "Equipment Designs for the Pickle House" is the result of long study by International Nickel Co.'s Development and Research staff. The applications of monel metal to the numerous types of pickling equipment required are covered in detail. Bulletin Ayx-45.

High Tensile Steels

Three types of high tensile steel particularly adapted to the transportation industries are described in a folder from U. S. Steel Corp. These are a chromium-copper-silicon steel for corrosion resistance, a medium manganese steel, and a strong structural silicon steel. Bulletin Mx-79.

Molybdenum in 1934

Climax Molybdenum Co. presents their annual book giving new developments in molybdenum, particularly as an alloy with iron and steel. The engineering data presented are made clear by many tables and illustrations. Bulletin Dc-4.

Ultropak

Two booklets are issued by E. Leitz, Inc., one containing description and catalog of their Ultropak microscope equipment, and the other a series of quotations and illustrations from scientists using the method. Get both by asking for Bulletin Ayx-45.

Metal Progress
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Please have sent to me without charge or obligation the following Literature described in the September issue. (Please order by number only.)

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Burnishing

(*Continued from page 60*) either before or after plating. This involves the smoothing of the surface by a rolling action without the removal of any metal, and is performed by rolling the work in the barrel with a large quantity of hardened and polished burnishing balls, ball cones, or similar materials. The size and shape of the balls must be adapted to the work to be done; the balls must not stick in any holes in the work. Proper pins and cones must also be added to the mixture to reach all corners in the parts. For a very high grade burnished surface, the work should go through a cutting down process before the burnishing process. However, for a large variety of low priced hardware, buttons, or overall buckles, this is unnecessary, since the parts are usually made of cold rolled strip.

For good burnishing, absolute cleanliness is necessary. This applies to the work, burnishing material and the burnishing barrel. A compound is usually added in the form of a high grade neutral soap. Any scale or dirt on the work will form a black, sticky scum which is difficult to remove and which prevents metal-to-metal contact with the polished steel balls. Some work may be dry burnished with a mixture of steel balls, leather scrap and sawdust and cob meal.

A large variety of metal parts is being successfully finished in this way, ranging from small bronze castings and steel and brass stampings to larger stampings (such as roller skate frames) and comparatively large die castings. The small parts, of course, are charged in the barrel loose and mixed with the burnishing material. Larger parts must be held in racks to prevent the pieces nicking each other or coming in contact with anything but the balls, yet be in position so that all surfaces are reached by the balls.

Plated work is usually burnished both before and after plating. Burnishing before plating requires from 40 min. up depending on the initial condition of the work; burnishing after plating requires about 20 min.

Finally it may be said that in all barrel finishing operations the best results require a careful study, taking into consideration the nature of the material, size of the pieces, original surface, finish required, and permissible cost. If the equipment is properly suited to the work, satisfactory results will follow.

Steam Turbines

(Continued from page 39)

stabilized materials at higher temperatures than 1000° F. with total deformations so large that the initial flow doesn't matter. I don't know. But then what would you do in our region of lower temperature and deformation? We must do *something;* there are no 10 and 20-year tests to guide us and we don't propose to wait for them!

The figure at top of page 39 shows two typical shapes of curves from among many. The straighter curve is the 17,000-psi. curve from the last two graphs. It really is not straight, but after an initial flow it seems to be approaching a steady rate. The other curve is smoothly rounding and to date the steel is continually strengthening. My interpretation is that the straighter curve represents a stabilized material at "high temperature" in relation to the critical range mentioned above, while the hooked curve represents a material treated for high physical properties and operating at only a "moderately high temperature." (As a matter of fact, the hooked curve is for material tested at a higher actual temperature, but then it is a different material.)

Now who can devise a simple way of expressing such widely different characteristics so we can specify what we want and get it? Necessarily working compromises have been made. Most steels tested at 750 to 1000° F. and with stresses small enough to assure satisfactorily limited deformation show continually decreased rates of creep or, in other words, continually improved strength with service. The total creep, including the initial, appears to form an approximate basis for comparison between constant stress tests and "step down" tests in which the initial creep is applied more rapidly by stresses higher than exist after some degree of relief.

For the present until some more complete basis of design is found, it seems necessary for turbine designers to limit all comparison of creep strength to values determined in tests where total strains have not exceeded the small values tolerable in service. For how could anyone logically predict allowable stresses which would be acceptable for a long time from tests which have given impossibly large strains in a short time? For the present at least it is more reasonable to base predictions of satisfactory long time performance on tests which have met all reasonable requirements throughout their duration.